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SELF- VERSUS HAND-FEEDING FOR MARKET HOGS, WITH PARTICULAR REFERENCE TO EFFECTS ON CARCASS MEASUREMENTS AND QUALITY[1]

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Self-feeding as a scheme for reducing the labour cost in the production of market hogs is not a recent development. It is the generally accepted plan throughout the chief hog-producing centres of the United States and is extensively followed also in many sections of the Prairie Provinces in Canada. The comparative results of self- and hand-feeding practices, in so far as the live hog is concerned, are quite well known, and may be summed up by the statement that slightly more feed may be required per unit gain with the self-feeding, but that considerably less labour per pig is involved; the choice, therefore, is frequently determined by the relative cost of grain and labour. Little, if any, effect on the rate of gain should be expected unless hand-feeding is accompanied also by limited feeding.

Whether or not self-feeding, as compared to hand-feeding, results in any significant effect on the carcass is not so well established. Results obtained in the United States with fat-type hogs are not applicable to the problem of Canadian bacon production, and Canadian studies in market-hog production have not included carcass measurements or grade.

The question of the effects of self-feeding on carcass excellence has lately taken on added significance in Canada with the development of Swine Advanced Registry policy, which involves carcass excellence as one feature in the requirements for qualification. Experience during the first few years, since the institution of this scheme, has shown that there is a marked variation in carcass scores of pigs from various parts of the country, a part of which it is reasonable to suppose may be traced to differences in feeding practice, and particularly to the skill of different feeders.

This situation may seriously interfere with an unbiased rating of sows as to their hereditary or genetic worth as producers of ideal market hogs that will yield excellent carcasses. Kinds of feeds, general feeding and management practice may be specified and hence in some measure kept alike from station to station, but unfortunate indeed is the sow with desirable genetic make-up for the production of "select" pigs, whose progeny when submitted to feeding test fall into the hands of an unskilled feeder. Perhaps worse, in the long run, is the case of mediocre sows who receive a

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high rating which in reality should be credited to an exceptionally skilled feeder rather than to breeding worth.

If, therefore, some way could be found to eliminate the "human element" from the case, so that all sows would have as nearly equal a chance as possible to qualify, *i.e.*, to demonstrate their genetic characteristics in so far as feed and management are concerned, it would be in the interests of the swine industry generally. Self-feeding, in many respects, appears to be such a method. But before it can safely be adopted, it must be certain that such a method would have no undesirable effects on the excellence of the carcass produced.

It was for the purpose of obtaining information on this question that this feeding trial was undertaken.

EXPERIMENTAL

Animals

Forty purebred Yorkshire pigs from the herd at Macdonald College were chosen for this test. They were taken from seven litters all by the same sire, and of which the dams were half-sisters. The pigs were penned and fed individually, starting on test when weaned (about 56 days old). From each litter, as it reached weaning age, the pigs were allotted at random into two groups, Lot I to be hand full-fed, and Lot II to be self-fed.

Feeding

The self-fed pigs had free access to individual self-feeders placed in each pen. Water was supplied *ad libitum* in special water buckets. The hand-fed pigs were fed three times per day, the dry meal allowance for each feeding being measured into their troughs and the water allowance. poured over it. Quantities were adjusted to appetite as gauged by what the pigs would clean up readily in 15 minutes at each meal.

Feeding three times per day was followed for two reasons: partly to ensure, if possible, that the hand-fed pigs would eat as much feed per day as the self-fed group, and partly because the more frequent feeding simplified the problem of avoiding frozen feed during the cold weather. (No artificial heat was provided in the piggery.)

Rations

The meal mixture used was the same for all pigs. The basic feed consisted of equal parts by weight of barley meal and hominy feed. The protein supplement was made up of:

Tankage	400	Ground limestone	23
Fish meal	200	Salt	20
Linseed oilmeal	200	Cod liver oil	5
Soyabean oilmeal	100	Ferric oxide	2
Bone char	50		

This protein-mineral supplement constituted 20% of the ration for the first 30 days of feeding, 15% for the second 30 days, and 10% for the balance of the feeding period to market weight.

Weights and Measures

All pigs were weighed, and their feed consumption during the lapsed period was checked at regular intervals. Pigs were shipped as they reached a market weight of about 200 pounds. Degree of finish of the individual

hog was considered in determining the exact time of slaughtering for any individual case.

Pigs were marketed through the Montreal Branch of Canada Packers and graded into market classes by the Dominion Live Stock Branch Hog Graders on duty at that plant. Necessary carcass measurements and grading were also done by Dominion agents, according to procedure laid down for carcasses of hogs from Advanced Registry Feeding Stations.

In addition to these items, the area of the bacon rasher and its proportion of lean were determined by the following procedure: a section of the left side of each carcass, about three inches wide and running from back to belly at approximately the third lumbar vertebra, was cut, frozen, and split on a saw, thus giving a hard, flat surface of a full bacon rasher. The surface area of this rasher and of the lean portions were then determined by the use of a planimeter.

Carcass Score

In order to express the relative excellence of carcasses, a scheme of numerical scoring was followed. This was patterned after the one used in the Swine Advanced Registry, modified to be suitable for a single carcass. (The Advanced Registry Score involves four carcasses.) Under this plan, the carcass score is obtained by deducting from a perfect score (100), a predetermined number of points for specified faults. The relative weight of the items on which the perfect score is based and the relative seriousness of faults have been accepted as laid down in the Advanced Registry policy. Whatever the merits or demerits of this score in Advanced Registry work, it serves in this problem as a useful basis for the comparisons to be made in this study.

The details of the scoring were as follows:—

Measurement	Perfect score	Deductions
Length (1st rib to aich bone)	24	4 for each ½ inch under 30½ but over 29½ inches. 24 for carcasses less than 29½ inches.
Depth of fat (along the back)	12	8 for a depth of fat over 2 inches or under 1 inch.
Uniformity of fat	12	8 for a difference greater than ¾ inches between maximum and minimum fat depth.
Per cent ham	9	1 for each per cent below 25% of the total weight of ham, middle and shoulder.
Per cent middle	9	1 for each per cent below 50% of the total weight of ham, middle, and shoulder.
Per cent shoulder	9	1 for each per cent above 25% of the total weight of ham, middle, and shoulder.
Grade of belly	25	Excellent—No deduction. Good — 8 points deduction. Fair —16 points deduction. Poor —24 points deduction.
Carcass over 160 lb.	—	8 points deducted from final score above.

RESULTS

The complete data for individual pigs is shown in appendix Table I. A summary of gains, feed consumption, and live grading is given in Table I below.

TABLE I.—GAINS, FEED CONSUMPTION, AND LIVE GRADING OF PIGS

——	Hand-fed hogs	Self-fed hogs
Number of pigs	20	20
Days fed to marketing	114.5	121.6
Initial weight	35.7	35.1
Daily gain	1.50	1.37
Feed eaten	653.0	673.0
Gain per 100 lb. feed	26.3	24.9
Shipping weight	206.5	199.5
Live grading—		
Number of selects	10	7
Number of bacons	10	13

Examination of this table leads to the suggestion that self-feeding may be questionable practice in so far as the live grading of the hog is concerned. At least a week longer was required in reaching market weight, and this at greater feed cost. In addition, a smaller proportion of "select" hogs was produced. In this connection, it should be mentioned that considerable difficulty was encountered in keeping water

TABLE 2.—AVERAGE CARCASS MEASUREMENTS*

——	Item	Hand-fed hogs	Self-fed hogs	Weighted average Hand and Self-fed hogs
Hogs grading "select"	No. hogs	10	7	17
	Shipping weight	206	212	209
	Carcass length	30.70	30.70	30.70
	Neck fat	2.16	2.21	2.18
	Back fat	1.26	1.34	1.30
	Loin fat	1.72	1.77	1.74
	Min. thickness belly	.70	.66	.68
	Area of rasher	26.26	27.69	27.07
	Area eye muscle	4.53	4.75	4.64
	Area lean in rasher	10.87	11.53	11.20
	Per cent lean in rasher	41.33	41.70	41.50
Hogs grading "bacon"	No. hogs	10	13	23
	Shipping weight	207	193	200
	Carcass length	30.97	29.50	30.30
	Neck fat	2.04	2.11	2.07
	Back fat	1.14	1.19	1.16
	Loin fat	1.59	1.60	1.59
	Min. thickness belly	.70	.69	.70
	Area of rasher	25.25	25.21	25.23
	Area eye muscle	4.93	4.61	4.77
	Area lean in rasher	10.92	10.95	10.93
	Per cent lean in rasher	43.34	43.50	43.42
Weighted average, Selects and Bacons	Shipping weight	206	200	
	Carcass length	30.80	29.90	
	Neck fat	2.10	2.16	
	Back fat	1.20	1.25	
	Loin fat	1.65	1.66	
	Min. thickness belly	.70	.68	
	Area of rasher	25.85	26.07	
	Area eye muscle	4.73	4.65	
	Area lean in rasher	10.89	11.15	
	Per cent lean in rasher	42.33	42.28	

*Weights in pounds, measured in inches.

available to the self-fed pigs. Extreme cold made it necessary on many days to break the ice from the water every hour. This situation doubtless penalized the self-fed group somewhat in so far as gains and feed consumption were concerned.

Whether or not these effects were reflected in the carcass measurements is shown in Table 2. The data have been arranged to show comparisons between self- and hand-feeding for both "select" and "bacon" grades of pigs.

Study of this Table fails to reveal any appreciable effect of self feeding on average carcass measurements of the hogs grading "select". Among those which graded as "bacons" at the market, one item of considerable importance is to be noted, namely, that the carcasses of the self-fed hogs were on the average *1.47 inches shorter* than those hand-fed. Taking all hogs, this difference amounts to about seven-eighths of an inch. That this may be a serious matter is quite evident when the carcass scores are compared, as in Table 3. (Complete data on scores will be found in Appendix Table 2.)

TABLE 3.—AVERAGE CARCASS SCORES

	Hand-fed hogs	Self-fed hogs		Weighted average using adjusted scores
		Observed	As adjusted*	
Selects	64.3	59.6	63.0	63.8 ± 2.05
Bacons	57.1	49.0	56.4	56.7 ± 1.76
Weighted average	60.7 ± 1.89	52.8	57.8 ± 1.89	59.7

* See text adjoining.

Reference to Appendix Table 2, shows that out of the 20 hogs self-fed one "select" and seven "bacons" had sides measuring under 29.5 inches, and thereby received the maximum penalty for this fault. The effect on the average scores is evident from Table 3. Statistical analysis indicates that odds are more than 100 to 1 that this difference is chargeable to the feeding practice.

That breeding was a relatively unimportant factor in this condition (its effects were largely eliminated by the allotment procedure) is clearly evident when the measurements of length are grouped by sows as in Table 4. In all litters save one, the self-fed pigs were shorter on the average than those hand-fed.

TABLE 4.—CARCASS LENGTHS, GROUPED BY SOW

Sow No.	104	105	107	110	121	122	123
Self-fed pigs	31.25 30.50	29.125 30.625 29.000 31.750	30.500 30.000	30.375 30.250 30.500 28.875	29.375 29.375	28.500 29.500 28.875 29.000	30.500 31.125
Average	30.875	30.063	30.250	30.000	29.375	28.969	30.813
Hand-fed pigs	31.75 31.125	31.125 33.000 31.000 31.250	31.125 29.500 32.375	29.750 28.625 29.750	30.500 29.375 30.000 30.500	29.250 30.000	31.250 32.625
Average	31.437	31.594	31.000	29.458	30.094	29.625	31.937

Other than for length of side, however, the method of feeding appeared to have no significant effect on carcass excellence as indicated by score. This is clearly demonstrated by the "adjusted scores" (Table 3) obtained by adding to the length of each of the carcasses of the self-fed hogs the amount by which the self-feeding appears on the average to have shortened the carcasses, and then rescoring them. When this is done, practically all the difference in score between self- and hand-feeding disappears, both in the "bacon" and in the "select" groups.

In interpreting this result, it must be remembered that length is relative, and with hogs normally yielding carcasses well over the minimum demanded, the effects of self-feeding on carcass score would be much less serious than is the case in these data.

"Selects" versus "Bacons"

While not a matter of primary consideration in this study, the data assembled throw some light on the accuracy of live hog grading, in indicating probable carcass excellence. Examination of the individual carcass scores of the 40 pigs, using the corrected scores in the case of the self-fed group, reveals the fact that there is considerable overlapping of scores between the two top market grades (see appendix Table 3). The variability of the scores is measured by a standard deviation of 8.45 (general mean score = 59.725). If we take odds of 19 to 1 as satisfactory reliability, then any individual carcass score from 42.8 to 76.6 must be considered as probably belonging to pigs of the same population. Only pigs in this test having carcass scores of 77 or higher may safely be considered as belonging to a group of actual greater excellence. Of the 40 pigs in this test, the distribution of these superior pigs (scores) is as follows:

Self-fed		Hand-fed	
Selects	Bacons	Selects	Bacons
1	1	1	0

This would seem to indicate that there may be many excellent carcasses cut from "bacons" and that too much stress should not be laid on differences between "bacons" and "selects" in hoof grading. In fact, the data of this test leads to the conclusion that the chief, if not the only, effective distinction which should be used to separate "selects" from "bacons" in so far as such separation has any bearing on carcass excellence, is length of hog.

SUMMARY

In this test an attempt was made to learn whether or not self-feeding might have any undesirable effect on carcass excellence of pigs intended for bacon production. Results indicated that the carcasses of self-fed pigs were on the average shorter by about $\frac{7}{8}$ inch than those of pigs full hand-fed on slop feed. Otherwise the carcasses of the two groups were not significantly different. Self-fed pigs, however, required slightly longer (7 days) to reach market weight, the rates of gain being 1.50 and 1.37 pounds per day for hand- and self-fed pigs respectively. Feed required per 100 pounds gain was 383 and 409 pounds, the hand-fed pigs requiring about 50 pounds less feed each to reach 200 pounds market weight. Some of this difference between the two groups in rate of gain may have been due to difference in water intake during the severe cold weather, when it was difficult to keep water from freezing in the buckets of the self-fed pigs.

Further data are needed before satisfactory conclusions can be drawn.

Appendix Table 1.—Summary of data—Experiment No. 53

——	Hand-fed lot																				
Pig No.	356	357	374	390	377	360	385	348	347	354	336	337	384	326	320	333	350	338	309	311	Av.
Days fed	112	138	112	112	125	112	91	119	100	100	114	133	100	114	114	114	119	133	114	114	114.5
Initial weight	36	32	33	35	31	38	41	37	36	44	29	31	39	39	33	35	39	27	35	44	35.7
Daily gain	1.40	1.20	1.44	1.48	1.42	1.46	1.69	1.62	1.67	1.69	1.52	1.28	1.60	1.62	1.54	1.54	1.43	1.36	1.58	1.53	1.5
Total gain	157	165	161	165	178	164	154	193	167	169	173	170	160	185	175	175	170	181	180	174	170.8
Feed eaten	624	703	617	646	654	686	571	695	581	586	665	704	548	703	630	682	652	731	696	677	652.55
Gain per 100 lb. feed	25.2	23.5	26.1	25.5	27.2	23.9	27.0	27.8	28.7	28.8	26.0	24.1	29.2	26.3	27.8	25.7	26.1	24.8	25.9	25.7	26.3
Shipping weight	193	197	194	200	209	202	195	230	203	213	202	201	199	224	208	210	209	208	215	218	106.5
Live grade	S	B	S	S	B	B	S	S	S	B	B	B	S	S	B	S	S	B	B	B	S=50%
Carcass grade	LL	LL	L	P	LL	LL	P	L	L	V	L	LL	P	L	P	LL	L	P	LL	P	
Carcass weight	150	156	147	156	156	156	149	173	157	162	155	152	147	176	157	167	157	161	161	166	158.05
Carcass length	31.1	31.3	31.3	29.8	32.6	32.4	28.9	33.0	31.1	31.3	29.4	30.0	29.8	30.0	29.3	30.5	31.0	30.5	31.8	31.1	30.81
Maximum neck fat	2.0	1.9	2.0	2.4	1.9	2.1	2.3	2.3	1.9	1.9	2.0	2.0	2.3	2.4	2.3	2.0	2.0	2.1	1.9	2.4	2.105
Minimum back fat	1.0	1.0	1.0	1.5	1.0	1.1	1.5	1.3	1.3	.9	1.1	1.0	1.5	1.3	1.5	1.1	1.1	1.3	1.0	1.5	1.2
Loin fat	1.5	1.6	1.6	1.9	1.5	1.6	2.0	1.8	1.5	1.3	1.8	1.5	1.9	1.6	1.6	1.5	1.5	1.6	1.5	1.9	1.6
Minimum thickness belly	.5	.4	.6	1.0	.8	.6	.8	.6	.6	.4	.9	.8	.6	.9	.9	.8	.6	.8	.6	.8	.7
Area of rasher	24.96	24.06	22.80	29.95	23.94	24.56	28.66	31.10	24.51	24.42	25.87	26.38	24.72	28.51	26.78	25.25	24.16	26.34	24.64	25.50	25.85
Area of eye muscle	5.01	3.57	3.58	3.52	4.99	4.91	3.68	6.14	5.28	5.46	4.67	5.92	3.33	3.96	4.59	4.69	5.07	6.08	5.84	3.31	4.73
Total area of lean	11.71	8.70	9.33	9.26	10.51	11.95	9.52	14.40	11.25	13.25	10.42	13.18	9.42	11.30	10.50	10.80	11.76	10.14	12.70	7.86	10.90
Per cent lean in rasher	46.9	36.2	40.9	30.9	43.9	48.7	33.2	46.3	45.9	54.3	40.2	50.0	38.1	39.6	39.2	42.8	48.7	38.5	51.6	30.8	42.34
Length across eye	4.7	3.8	4.2	3.6	3.9	4.1	3.5	4.8	4.4	4.8	4.3	4.6	3.6	4.2	4.0	4.3	4.2	3.7	4.7	3.9	4.12
Width across eye	1.2	1.4	1.3	1.2	1.5	1.5	1.2	1.6	1.3	1.4	1.2	1.6	1.5	1.4	1.3	1.3	1.5	1.4	1.5	1.0	1.36
Product of length and width	5.64	5.32	5.46	4.32	5.85	6.15	4.20	7.68	5.72	6.72	5.16	7.36	5.40	5.88	5.20	5.59	6.30	5.18	7.05	3.90	5.70

APPENDIX TABLE 1.—SUMMARY OF DATA—EXPERIMENT NO. 53—*Concluded*

——	Self-fed lot																				
Pig No.	355	391	370	386	392	359	371	344	352	353	332	322	396	319	321	328	345	335	307	308	Av.
Days fed	125	112	112	112	110	138	112	119	100	134	135	133	100	135	114	114	119	133	162	114	121.6
Initial weight	35	33	33	34	32	36	39	38	34	44	29	33	38	36	32	34	38	28	35	41	35.1
Daily gain	1.19	1.54	1.38	1.51	1.73	1.11	1.60	1.35	1.48	1.37	1.19	1.28	1.52	1.15	1.34	1.41	1.52	1.22	1.05	1.48	1.37
Total gain	149	173	154	169	190	153	179	161	148	184	161	170	152	155	152	161	181	163	170	169	164.7
Feed eaten	740	595	598	591	557	641	829	682	538	734	672	901	611	570	566	763	750	745	740	640	673.15
Gain per 100 lb. feed	20.1	29.1	25.8	28.6	34.1	23.9	21.6	23.6	27.5	25.1	24.0	18.9	24.9	27.2	26.9	21.2	24.1	21.9	23.0	26.4	24.9
Shipping weight	184	206	187	203	222	189	218	199	182	228	190	203	190	191	184	195	219	191	205	210	199.8
Live grade	B	B	B	S	S	B	S	S	B	S	B	B	B	B	B	B	B	B	S	S	S=35%
Carcass grade	LL	P	LL	L	P	L	P	L	L	P	L	L	L	L	L	LL	P	LL	LL	L	
Carcass weight	143	164	141	151	165	149	167	147	138	176	146	157	145	150	138	146	171	150	156	166	153.3
Carcass length	30.5	30.3	30.5	30.4	30.5	30.0	31.1	29.1	29.0	31.8	29.4	28.9	28.6	28.5	29.5	29.0	30.6	29.4	31.3	30.5	29.9
Maximum neck fat	2.3	2.4	2.0	2.4	2.3	2.3	2.4	2.1	2.4	2.4	1.9	2.0	2.1	2.0	2.0	1.8	2.3	2.0	1.9	2.0	2.1
Minimum back fat	1.1	1.8	.9	1.1	1.8	1.8	1.5	1.1	1.3	1.5	.9	1.0	1.3	1.0	1.1	.9	1.5	.9	1.0	1.5	1.2
Loin fat	1.5	2.1	1.3	1.8	1.2	1.9	1.9	1.5	1.6	1.9	1.4	1.5	1.6	1.5	1.5	1.6	1.9	1.4	1.6	1.6	1.7
Minimum thickness of belly	.6	1.0	.5	.6	.8	.4	1.0	.6	.5	.6	.6	.9	.9	.9	.6	.9	.6	.6	.4	.6	.7
Area of rasher	23.04	29.71	21.28	25.66	28.58	24.61	28.82	26.03	22.96	27.98	23.78	27.06	26.22	25.30	22.80	26.21	29.23	25.52	23.98	32.77	26.01
Area of eye muscle	3.58	5.23	3.98	3.97	4.48	3.25	4.34	4.93	4.88	5.36	4.69	5.44	4.05	4.54	4.80	5.20	4.94	5.33	3.95	6.21	4.66
Total area of lean	9.84	11.73	9.78	10.58	10.30	8.19	10.98	11.63	10.64	10.88	11.73	11.12	10.40	12.80	10.61	11.95	11.49	12.03	11.44	14.90	11.15
Per cent lean in rasher	42.7	39.5	45.9	41.2	36.0	33.3	38.1	44.7	45.6	38.9	40.3	41.1	39.6	50.6	46.5	45.6	39.3	47.1	47.7	45.4	42.9
Length across eye	3.8	3.9	4.1	3.9	3.8	3.8	3.8	4.0	4.3	3.8	4.0	4.2	3.7	4.1	4.3	4.1	4.1	4.1	4.1	4.7	4.0
Width across eye	1.3	1.6	1.2	1.3	1.4	1.0	1.5	1.5	1.6	1.5	1.5	1.5	1.3	1.3	1.4	1.5	1.5	1.8	1.2	1.9	1.4
Product of length and width	4.94	6.24	4.92	5.07	5.32	3.80	5.70	6.00	6.88	5.70	6.00	6.30	4.81	5.33	6.02	6.15	6.15	7.38	4.92	8.93	5.83

APPENDIX TABLE 2.—DETAIL OF CARCASS SCORES, GROUPED ACCORDING TO FEEDING PRACTICE AND HOOF GRADING OF HOGS

	Self-fed pigs											Hand-fed pigs								
	Pig. No.	Length	Length* (a)	Depth fat	Uniform fat	Per cent ham	Per cent middle	Per cent shoulder	Grade belly	Total	Total (a)	Pig No.	Length	Depth fat	Uniform fat	Per cent ham	Per cent middle	Per cent shoulder	Grade belly	Total
Select hogs	307	24	24	12	4	8	6	6	1	61	61	326	20	4	4	9	4	4	9	36
	308	24	24	12	12	9	8	9	17	91	91	333	24	12	4	8	7	6	17	70**
	344	0	20	4	4	9	4	4	1	26	46	347	24	12	12	9	6	7	9	79
	355	24	24	4	4	8	8	7	9	56**	56**	348	24	4	4	7	7	5	9	60
	371	24	24	4	4	8	6	5	17	60**	60**	350	24	12	4	9	4	4	1	58
	386	20	24	4	4	8	6	4	17	63	67	356	24	12	4	9	4	4	1	58
	392	24	24	4	12	8	6	5	9	60**	60**	374	24	12	4	9	5	5	9	68
												384	16	4	12	9	7	8	9	65
												385	0	4	12	8	9	7	25	65
												390	16	4	4	8	9	8	25	74
	Av.			6.3	6.3	8.3	6.3	5.7	10.1	59.6	63.0		19.6	8.0	6.4	8.5	6.2	5.8	11.4	64.3
Bacon hogs	319	0	0	12	4	9	3	5	17	50	50									
	321	16	20	12	4	9	3	5	1	50	54									
	322	0	16	12	4	9	2	4	1	32	48									
	328	0	16	4	4	9	3	5	17	42	58	309	24	12	4	9	5	7	1	62
	332	0	20	4	4	9	5	7	1	30	50	311	24	4	4	9	8	7	17	73
	335	0	20	4	4	9	1	3	1	22	42	320	0	4	12	9	6	6	9	46
	345	24	24	4	12	7	7	5	1	52**	52**	336	0	12	4	9	6	6	17	54
	352	0	16	4	4	9	6	6	1	28	44	337	20	12	4	9	3	6	1	55
	355	24	24	4	4	9	6	6	1	52	52	338	24	4	4	9	5	7	9	62
	359	20	24	4	12	8	8	7	9	68	72	354	24	4	9	4	4	5	1	51
	370	24	24	4	4	8	5	4	1	50	50	357	16	12	4	9	5	7	1	54
	391	20	24	4	12	8	9	8	25	86	90	360	24	4	4	9	4	4	1	50
	396	0	16	4	4	9	7	7	25	56	72	377	24	12	4	7	5	3	9	64
	Av.		18.8	5.8	6.1	8.6	4.9	5.5	10.1	49.0	56.4		18.0	8.0	4.8	8.8	5.1	5.8	6.6	57.1

* Based on observed length plus ¾ inches. (see text).
** Indicates deduction was also made for overweight carcass (see scoring chart p. 531).

APPENDIX TABLE 3.—DISTRIBUTION OF CARCASS SCORES.
(LENGTH OF CARCASSES OF HAND-FED PIGS INCREASED BY $\frac{7}{8}$ INCHES BEFORE SCORING)

Self-fed		Hand-fed	
Selects	Bacons	Selects	Bacons
61	50	46	62
91	54	70	73
46	48	79	46
56	58	60	54
60	50	58	55
67	42	58	62
60	52	68	51
	44	65	54
	52	65	50
	72	74	64
	50		
	90		
	72		

TOTAL AND MEANS OF SCORES BY GROUPS SHOWN

——	Self-fed	Hand-fed	Hand-fed + Self fed
Selects	441 63.0	643 64.3	1084 33.76
Bacons	734 56.4	571 57.1	1305 56.73
Selects + Bacons	1175 58.75	1214 60.7	Total 2389 N = 40 General Mean 59.725

APPENDIX TABLE 4.—ANALYSIS OF VARIANCE OF CARCASS SCORES

Variance due to	Degrees of freedom	Sum of squares $S(x - \bar{x})^2$	Variance (σ^2)	Standard deviation (σ)
Total	39	3147		
Self *vs.* hand	1	38		
Select *vs.* bacon	1	471		
Error	37	2628	71.03	8.45

SIGNIFICANCE OF MEAN DIFFERENCES IN CARCASS SCORES (ODDS 19 : 1)

——	Mean difference	Standard error mean difference	Necessary difference P = 0.05
Self fed *vs.* hand-fed	1.95	2.68	5.20
Selects *vs.* bacons	7.03	2.76	5.38

Résumé

Alimentation des porcs de consommation à la trémie et à la main et effets de cette alimentation sur les mesures et la qualité de la carcasse. E. W. Crampton, Collège Macdonald, P.Q.

On se proposait de voir par cet essai si l'alimentation automatique des porcs, c'est-à-dire l'alimentation à la trémie, peut exercer un mauvais effet sur la qualité de la carcasse destinée à la production du bacon. Les résultats obtenus indiquent que les carcasses des porcs nourris à la trémie sont en moyenne de $\frac{7}{8}$ de pouce plus courtes que celles des porcs nourris à la main avec de la pâtée molle. Sous d'autres rapports les carcasses des deux groupes ne différaient pas de façon significative. Cependant, les porcs nourris à la trémie ont exigé un peu plus longtemps (7 jours) pour atteindre le poids de vente; le taux de l'augmentation de poids était respectivement de 1·50 et 1·37 livre par jour pour les porcs nourris à la main et ceux nourris à la trémie. La quantité d'aliments exigés pour 100 livres d'augmentation de poids était de 383 et de 409 livres; les porcs nourris à la main ont consommé environ 50 livres de nourriture de moins pour arriver au poids du marché, qui était de 200 livres. Une partie de cette différence entre les groupes en ce qui concerne le taux de l'augmentation peut être due à la différence dans la quantité d'eau absorbée pendant les grands froids quand il était difficile d'empêcher l'eau de geler dans les abreuvoirs des porcs nourris à la trémie. Il sera nécessaire de recueillir de nouvelles données sur cette question avant que l'on puisse aboutir à des conclusions satisfaisantes.

THE DETERMINATION OF THE EFFECT OF FATTENING ON THE CARCASS OF THE CHICKEN[1]

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The process of fattening consists largely of a deposition of fat. Harshaw (1) stated that the greatest change in the chemical composition of the carcass of the fattened chicken as compared with the unfattened chicken was in the fat content of the breast muscle, the remaining edible portion, and the total edible portion. This worker found that the fat in the breast muscle increased by about 85%, whereas the fat in the leg muscle increased by 43% of the original amount. The fat content of the breast muscle was only 0.55% before fattening; so that, although the gain was about 85%, the amount of fat was not large.

In studies of the effect of different cereals, rations, or length of feeding periods on the increase in fat, it is necessary to know something of the distribution of the fat in the bird's body. The deposition of fat in the body of the chicken differs from that in the body of the larger animals, in which a dispersion of fat within the muscles is to be found. In the chicken, the fat is found between and on the surfaces of the muscles, attached to the skin, and on the internal organs such as the gizzard, proventriculus, and intestines. Internal tissue fat is also accumulated in the liver. The fat deposits about the muscles of the breast, leg, and thigh are attached to the fascia of the muscles and do not naturally separate from the muscle when the skin is removed. Such fats are not true muscle fats, since they are not within the bundles of muscle fibres. However, they might be termed "perimuscular" fats, and as such have been considered as a part of the muscle in determining the effect of fattening on the carcass of the chicken.

Definition.—Perimuscular fat is the inter muscular fat intimately connected with the fascia, and the layer of fascial fat on the external surfaces of the muscles.

The object of this paper is to outline clearly the method of sampling used in the chemical analyses of carcasses resulting from various feeding trials, reported by Maw (2), and to indicate the degree to which the inclusion of the perimuscular fat alters the total fat content of the muscle group samples.

The general procedure to be followed in sampling the dressed poultry carcass depends on the desired data to be recorded. Where a physical analysis of the various edible and non-edible portions of the fresh carcass is to be made, the carcass is drawn, recording the initial dressed weight as well as the weights of all parts: the head, feet and shanks, neck, heart, liver, gizzard (drawn), abdominal fat, remaining entrails (which include the intestines plus the fat attached to them), lungs, kidneys, spleen, gullet, crop, and windpipe, as well as the contents of the gizzard. The entire skin of the neck remains as a part of the drawn carcass. The drawn

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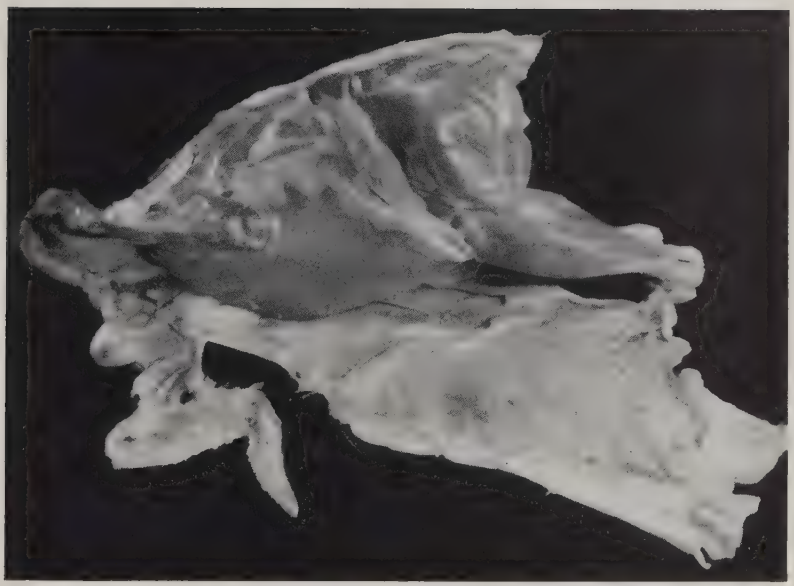

FIGURE 1. Showing deposits of perimuscular fat on the surface of the breast and leg muscles.

carcass plus the abdominal fat is considered as the drawn weight. In the further physical analysis of the drawn carcass to determine the proportions of the body represented by the skin, dark meat, light meat, and fresh bone, the skin is first removed by making a cut along the back from shoulder to tail. All external fat definitely attached to the skin is considered a part of the skin sample. All perimuscular fat is considered a part of the light or dark meat respectively as attached. The muscle meat is clearly defined as light meat on the breast and wing, and dark meat on the leg and thigh. In separating these two kinds of meat, the leg is disjointed at the hip and the muscles detached at their respective locations of attachment to the skeleton. If the thigh muscle is to be considered a separate sample from the lower leg, the separation is made at the main joint between the tibia and femur bones. Similarly the breast meat may be separated from the meat of the wing by detaching at the shoulder joint. The remaining bone sample includes all bones of the drawn carcass. The various samples are then weighed in grams.

In preparing such parts as the skin or abdominal fat for chemical analysis, the sample is placed in air-tight bottles for holding under refrigeration until being weighed prior to analysis. The entire muscle samples, however, are cut into strips and immediately ground, with thorough mixing between grindings, until homogeneous in consistency, and then packed in bottles for later sampling for analysis.

The method of chemical analysis used is that described by Holcomb and Maw (3).

The results of the inclusion of such perimuscular fats as a part of the muscle is given in Table 1. The samples for comparative fat analyses

TABLE 1.—THE FAT CONTENT OF THE BREAST AND THIGH MUSCLES RESULTING FROM TWO METHODS OF SAMPLING FROM EACH INDIVIDUAL CHICKEN
Leghorn Cockerels—12 weeks of age

Chicken number	Breast muscles			Thigh muscles		
	Left side (muscular plus perimuscular fat) Sample 1	Right side (Muscular fat only) Sample 2	Difference	Left side (muscular plus perimuscular fat) Sample 1	Right side (muscular fat only) Sample 2	Difference
582	2.6	1.1	1.5	11.3	6.4	4.9
527	3.7	0.9	2.8	9.4	5.6	3.8
1801	3.0	0.8	2.2	9.3	7.7	1.6
1733	3.1	1.2	1.9	10.0	9.5	0.5
743	2.7	1.1	1.6	7.3	5.7	1.6
567	3.2	1.3	1.8	8.3	5.3	3.0
1795	2 4	1.0	1.4	8.6	6.3	2.3
449	2.1	1.1	1.0	8.5	6.3	2.2
1764	2.2	1.9	0.3	8.3	4.7	3.6
1786	3.8	1.3	2.5	9.3	3.4	5.9
1798	2.6	1.1	1.5	4.7	4.3	0.4
1788	3.9	1.2	2.7	12.0	7.5	4.5
1759	3.3	1.4	1.9	9.2	7.2	2.0
1761	2.7	2.6	0.1	8.3	5.4	2.9
1765	2.8	1.3	1.5	8.9	6.9	2.0
Total	44.1	19.3	23.7	133.4	92.2	41.2
Mean	2.939±0.0145	1.286±0.0114	1.646±0.0228	8.893±0.0431	6.146±0.0390	2.746±0.0404

were taken from 12-week-old White Leghorn cockerels which had been individually fed for 14 days with a ration of yellow cornmeal supplemented by 6% animal protein and 5% chicken fat. The breast and thigh muscles of each bird were removed. The perimuscular fat attached to the muscles on the left side of the body was analysed as a part of the muscle sample, while that on the muscles of the right side was removed and the muscle only analyzed. A portion of the perimuscular fat lies between the muscles and can only be removed by separating the muscles; such fat, however, was removed from the samples of the right side of the body.

The data given in Table 1 show that in the case of the breast muscle the perimuscular fat was responsible for an increase of $1.646 \pm 0.0228\%$ in the fat content, while the perimuscular fat attached to the thigh muscle increased the fat content by $2.746 \pm 0.0404\%$. The perimuscular fat on the surface of the breast muscles represents a larger proportion of the total fat than that within the muscles themselves. In the case of the thigh muscles the perimuscular fat represented about one-third of the total fat.

In separating the individual muscles, it was observed that the deposits between the muscles of the thigh were larger than those between the muscles of the breast. In view of the difficulty of removing the perimuscular fat, particularly that lying between the muscles, it is believed that the perimuscular fat attached to the fascia surface should be analysed with the muscle flesh. By this method the percentage of fat includes the fat of the muscle and the total perimuscular fat (made up of the surface fat and that between the muscles).

SUMMARY

Perimuscular fat is defined as the intermuscular fat intimately connected with the fascia, and the layer of fascial fat on the external surfaces of the muscles.

In studies of the distribution of fat in the body, perimuscular fat is believed to be a logical part of the sample of the breast or thigh muscles for the determination of the fat content of such groups of muscles, where the removal of all perimuscular fat is practically impossible.

There are significant differences in the fat content of the breast and the thigh muscles where two different methods of sampling are used, the one including the perimuscular fat and the second the muscular fat only.

ACKNOWLEDGMENT

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Résumé

Détermination de l'effet de l'engraissement sur les carcasses des poulets. W. A. Maw et I. E. Puddington, collège Macdonald, P.Q.

La graisse périmusculaire est la graisse intermusculaire intimement reliée au fascia et à la couche de graisse fasciale sur les surfaces externes des muscles. L'étude de la distribution de la graisse dans le corps porte à croire que la graisse périmusculaire forme logiquement partie des muscles de la poitrine ou de la cuisse pour la détermination de la proportion de graisse de ces groupes de muscles, où il est pratiquement impossible d'enlever toute la graisse périmusculaire. Il y a des différences significatives dans la proportion de graisse dans les muscles de la poitrine et de la cuisse lorsque l'on emploie deux méthodes différentes d'échantillonnage, celle qui comprend la graisse périmusculaire et celle qui ne comprend que la graisse musculaire.

THE PHYSIOLOGY OF *RHIZOCTONIA SOLANI* KÜHN

V. THE ACTIVITY OF CERTAIN ENZYMES OF *RHIZOCTONIA SOLANI* KÜHN[1]

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In the course of a series of investigations upon the physiology of *Rhizoctonia Solani*, strains were isolated from material of widely different origins, and apparently identical cultures obtained. Because of their occurrence on distinct hosts, it was considered that they might represent definite physiological strains. In view of the absence of distinctive morphological characters it seemed advisable to devise some biochemical test to identify strains. In the following experiments a comparison was made of the invertase activities of several strains in order to determine whether such studies offered a possible basis for their classification.

From preliminary results, however, it was apparent that differentiation of strains could not be accomplished satisfactorily by the evaluation of invertase activity alone. In the hope of developing a more suitable technique for this purpose, the influence of various nitrogen compounds upon enzyme activity was studied.

PART I.

THE DIFFERENTIATION OF PHYSIOLOGICAL STRAINS OF *RHIZOCTONIA SOLANI*

Experimental Procedure

A liquid synthetic medium of the following composition was prepared and found to be satisfactory for the growth of the fungus.

$FeCl_3$	0.001 gm.
$CaCl_2$	0.20 gm.
$MgSO_4 \cdot 7H_2O$	0.20 gm.
NaCl	0.20 gm.
KH_2PO_4	0.50 gm.
KNO_3	0.33 gm.
$(NH_4)_2SO_4$	0.22 gm.
Peptone ("Bacto")	4.53 gm.
Dextrose	10.00 gm.
Sucrose	10.00 gm.
Distilled water to a volume of 1 litre.	

After sterilization, 500 ml. quantities of the above nutrient medium, in one-litre Erlenmeyer flasks, were inoculated in the following manner. Petri dish cultures of potato dextrose agar were used and each dish inoculated with one of the strains of *Rhizoctonia Solani*. After incubation for three days at 25° C., 5 mm. discs were cut from the outer edge of the mycelial growth with a sterile cork borer. These discs were then transferred to

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[2] Graduate assistant.

[3] Pathologist-in-charge.

the surface of the liquid medium in the flasks with a sterile needle. Care was taken to float the disc on the surface as near the centre as possible in order to provide a uniform growth. All cultures were prepared in duplicate.

After incubation for a period of eighteen days at 25° C., the culture medium was separated from the mycelial mat by straining through cheese-cloth. Such filtrates were kept free from contamination by storage in the refrigerator after the addition of a small amount of toluene. Over periods of storage up to seven days, no appreciable loss in enzyme activity was noted.

Determination of the invertase activity of the filtrates was then carried out in the following manner. Reaction mixtures were prepared containing 10 ml. culture filtrate, 10 ml. citric acid-phosphate buffer, pH 4.0 (1), and 5 ml. 12.5% sucrose solution, and placed in 75 ml. test-tubes. The tubes in all series were prepared at 6-minute intervals in order to allow for the 6 minutes required for each in their subsequent analyses. After the addition of 1 ml. toluene to the surface of each reaction mixture, the tubes were corked and incubated for 24 hours at 25° C.

At the end of this period, 5 ml. samples were withdrawn from each tube and the reducing sugar content determined by the Munson and Walker method (2), the weight of reduced copper being obtained by the volumetric permanganate method. From these values were subtracted blank values determined by the analysis of similar reaction mixtures immediately after their preparation. All such measurements were carried out in duplicate.

The resulting weights of cuprous oxide were then taken as an index of the invertase activity of the various strains of *Rhizoctonia Solani*.

Table 1.—Invertase activity of several strains of *Rhizoctonia Solani* Kühn, expressed as milligrams cuprous oxide

Strain No.	Host	Invertase activity as cuprous oxide	
		A	B
		mg.	
1	Reward wheat	179.0	183.5
		166.5	171.3
		191 5	187.6
		173.	187.2
2	Pea seedling	111.7	126.0
		94.3	98.6
		87.8	85.3
		103.8	97.4
3	Ceres wheat	52.9	52.9
		45.6	45.6
		64.0	65.2
		58.7	54.6
4	Potato tuber	32.2	30.8
		37.8	37.1
		32.9	30.7
		35.7	37.1
		38.2	36.4
5	Aster root	35.1	37.8
		39.2	40.7
		35.0	36.5
		37.2	39.1
6	Durum wheat	27.8	27.8
		26.2	25.9
		24.3	24.5
		27.1	26.5
7	Ginseng root	10.1	15.7
		17.8	20.0
		20.4	19.2
		18.7	20.8

Results

In Table 1 are recorded the invertase activities of the culture filtrates of several physiological strains of *Rhizoctonia Solani*, expressed in terms of milligrams of cuprous oxide. The values given, A and B, represent those obtained

from duplicate cultures of the fungus and are the mean of duplicate sugar determinations.

PART II

THE INFLUENCE OF CERTAIN NITROGEN COMPOUNDS UPON THE ENZYME ACTIVITY OF *RHIZOCTONIA SOLANI* IN LIQUID CULTURE

Experimental Procedure

As a basic or full nutrient medium, that previously described was employed. When the sole source of nitrogen consisted of potassium nitrate, both the ammonium sulphate and peptone were omitted and the amount of the former salt increased to 1.01 grams per litre. With peptone as the sole source of nitrogen, all other nitrogenous compounds were omitted and the peptone ("Bacto") content increased to 13.6 grams per litre. Similarly, 0.66 grams ammonium sulphate, 0.3 grams urea, and 7.8 grams gelatin respectively were substituted as the sources of nitrogen in other media. In order to determine whether the addition of starch to the culture medium would induce a greater diastatic activity, 0.5% soluble starch was added to duplicate, full nutrient cultures.

Erlenmeyer flasks of one and two litre capacities were filled with one-half and one litre volumes respectively of the nutrient media and inoculated in the manner previously described, with Strain 4 isolated from sclerotia on potato tubers. The cultures were incubated for a period of approximately 40 days at 25° C. At the end of this time the mycelial mats were separated from the culture media, rinsed with distilled water, and dried to constant weight. The culture filtrates were preserved by the addition of toluene and by storage in a refrigerator.

Determinations of the invertase activity of the filtrates were carried out as before. The diastase activities of the filtrates were measured in a similar manner, after substituting a 2.5% solution of soluble starch as substrate and buffering the reaction mixtures at pH 5.0. The resulting weights of cuprous oxide were then taken as indices of the diastase and invertase activities of the potato strain of *Rhizoctonia Solani*.

In addition to determinations of the invertase and diastase activity, the catalase activity was measured in several filtrates. To evaluate the catalase activity, 10 ml. volumes of the culture filtrates were mixed with 10 ml. of the citric acid-phosphate buffer, pH 7.0 and 5 ml. of 3% hydrogen peroxide. The resulting reaction mixtures were placed in fermentation tubes and incubated for three hours at 25° C. At the end of this period, the amount of gaseous oxygen evolved was observed and was taken as the index of catalase activity.

Results

In Table 2 are recorded the invertase and diastase activities of culture filtrates of *Rhizoctonia Solani*, expressed in terms of milligrams of cuprous oxide. Catalase activity is expressed as millilitres of gaseous oxygen. As an index of the growth of the fungus in each type of nitrogenous medium, the dry weight of the mycelial mat of each culture is included. Each pair of values given represents duplicate cultures and are the mean of duplicate analyses made on each reaction mixture.

TABLE 2.—THE INVERTASE, DIASTASE, AND CATALASE ACTIVITIES OF CULTURE FILTRATES OF *Rhizoctonia Solani* KÜHN AS INFLUENCED BY THE SOURCE OF NITROGEN

Nitrogen source	Medium volume	Dry weight of mycelium	Invertase activity as cuprous oxide	Diastase activity as cuprous oxide	Catalase activity as gaseous oxygen
	ml.	gm.	mg.	mg.	ml.
Full nutrient	500	2.67	197.0	17.1	0.2
	1000	5.82	195.0	20.7	0.3
	1000	5.50	137.0	33.2	0.1
	500	3.95	126.0	28.1	0.1
	1000	7.67	117.0	18.6	
	1000	8.33	112.0	19.2	
	1000	5.72	144.3	24.8	
	1000	6.14	153.2	23.1	
0.5% soluble starch	500	3.88	212.0	23.2	0.2
	500	3.45	245.0	21.5	0.0
Potassium nitrate	1000	6.32	7.0	3.6	0.3
	1000	7.42	32.9	2.8	0.4
	500	3.31	29.2	3.5	
	1000	6.42	25.6	3.2	
	1000	6.62	61.6	5.6	
	1000	6.62	56.6	5.4	
Peptone ("Bacto")	1000	6.45	220.0	36.0	1.7
	1000	6.63	217.0	33.8	1.5
	1000	4.63	141.2	22.6	
	1000	5.65	152.4	19.7	
	1000	5.94	172.9	28.6	1.9
	1000	5.73	175.0	25.3	1.8
Gelatine	1000	11.45	55.1	6.2	0.0
	1000	10.85	56.3	5.8	0.0
	500	4.39	20.7		
	500	4.19	20.7		
Urea	1000	2.36	22.5	1.8	0.2
	500	1.15	17.7	2.5	0.2
	1000	3.42	36.2	4.4	
	1000	3.13	30.6	4.7	
Ammonium sulphate	500	0.50	29.6	3.2	0.4
	500	0.40	22.0	5.7	0.3
	1000	1.08	32.4	4.5	
	1000	1.15	35.7	4.8	

DISCUSSION

It is apparent from the variations in enzyme activity presented in Table 1 that several of the forms of *Rhizoctonia Solani* examined are distinct physiological types. In no other way is it possible to account for the divergence observed in their ability to produce invertase.

36434—2½

Of the strains employed, Strain 1, isolated from Reward wheat proved to be the highest in invertase activity while Strain 2, isolated from a pea seedling was only slightly less active. The activities of Strains 3 and 6, also isolated from wheat, were considerably lower than Strain 1. Strain 4 obtained from sclerotia on a potato tuber, was practically equivalent in activity with Strain 5, from aster roots. Strain 7, isolated from a ginseng root exhibited the lowest activity of all.

It is probable, therefore, that such variations in biochemical behaviour may prove valuable in the differentiation of physiological strains of *Rhizoctonia Solani* and other fungi.

From the variations in enzyme activity recorded in Table 2, it is apparent that the source of nitrogen in the nutrient medium exerts a marked effect upon the metabolism of *Rhizoctonia Solani*. In spite of the fairly uniform mycelial growth obtained in most cases, wide differences in the activities of both invertase and diastase may be noted.

With the gelatine as the source of nitrogen, a heavy, spongy growth resulted but the invertase activity was relatively low. With peptone, however, enzyme activity was equally as high as that of the full nutrient medium in which all types of nitrogen compounds were represented. The potassium nitrate medium on the other hand, with a mycelial growth almost equivalent to that of the peptone and full nutrient media, produced only a low enzyme activity. In the ammonium sulphate medium, in comparison to the amount of growth, the invertase and diastase activities were relatively high. Urea as a source of nitrogen was unfavourable for both growth and enzyme production.

In no case was the diastase of *Rhizoctonia Solani* particularly active. An attempt was made to stimulate the production of this enzyme by the addition of soluble starch to the full nutrient medium. Although the starch had been completely utilized by the fungus during its growth as determined by the starch-iodine test, no significant increase in diastase activity became apparent.

Catalase activity in general, was found to be low. The highest values noted were those obtained in the peptone medium. With gelatine no catalase activity whatever could be observed over the incubation period employed.

The most striking differences in enzyme activity appear in the peptone and gelatine media. With peptone as the nitrogen source, the activity of all enzymes is high. With gelatine, their activity is relatively low. It seems probable, therefore, that peptone, in contrast with gelatine, is more readily utilized by *Rhizoctonia Solani* in the elaboration of the enzymes invertase, diastase and catalase.

Sherman and Walker (3), however, have reported that amino acids exert a stimulating effect upon the activity of malt diastase. Diastase and presumably other enzymes as well, rapidly deteriorate in an aqueous solution. This loss in activity the authors believe to be due to the hydrolysis of the enzyme, and they ascribe the favourable influence of amino acids upon diastase to the protection of the enzyme from hydrolysis. This effect may also apply to the other enzymes. If, as suggested above, the fungus is able to hydrolyse peptone more effectively than gelatine, the presence of higher concentrations of amino acids may explain the increased enzyme activity in such cultures.

SUMMARY

A number of strains of *Rhizoctonia Solani* that could not be separated by morphological means have been distinguished by their enzyme activities. The invertase activities of three strains isolated from Reward, Ceres, and a Durum wheat were found to be distinct, indicating that several physiological forms may attack the same plant species. On the other hand, the invertase activities of two strains from aster and potato respectively, were similar, suggesting that strains on distinct species may be identical. It is suggested, therefore, that enzyme activity data may provide a possible basis for the classification of physiological strains of *Rhizoctonia Solani*.

The catalase, diastase, and invertase activities of culture filtrates were altered to a marked degree by the nature of the nitrogen compounds in the nutrient media. The enzyme activity was high when peptone was used as the sole source of nitrogen in the nutrient medium. The addition of nitrate and ammonium salts did not increase the activity over that obtained with peptone alone. In other media containing either gelatine, potassium nitrate, ammonium sulphate, or urea, the enzyme activity was low. It is suggested that the apparent stimulating effect of peptone may be due to its protective influence against hydrolysis of the enzymes.

ACKNOWLEDGMENT

The authors wish to acknowledge their indebtedness to Dr. F. J. Greaney of the Dominion Rust Research Laboratory, Winnipeg, Manitoba, who supplied the cereal strains of the fungus used in these experiments.

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Résumé

La physiologie de *Rhizoctonia solani* Kuhn. V. L'action de certains enzymes du *Rhizoctonia solani* Kuhn. H. I. Edwards et Wm. Newton, Laboratoire fédéral de phytopathologie, Saanichton, C.-B.

Un certain nombre d'espèces de *Rhizoctonia solani* qui ne pouvaient être séparées par des moyens morphologiques, ont été différenciées par l'action de leurs enzymes. Il a été constaté que l'invertase de trois espèces de rhizoctonies prises sur les variétés Reward, Cérès et un blé Durum a une action distincte, indiquant que plusieurs formes physiologiques peuvent attaquer la même espèce de plantes. D'autre part, l'action de l'invertase de deux espèces prises sur l'aster et la pomme de terre respectivement était semblable, donnant à croire que des espèces apparaissant sur différentes plantes peuvent être identiques. Les auteurs prétendent donc que les données relatives à l'action des enzymes peuvent fournir une base possible pour la classification des espèces physiologiques de *Rhizoctonia solani*. L'action de la catalase, de la diastase, et de l'invertase des filtrats de culture a été modifiée à un degré prononcé par la nature des composés azotés dans les milieux nutritifs. L'action enzymotique était forte lorsque la peptone était employée comme source unique d'azote dans le milieu nutritif. L'addition de nitrate et de sels d'ammonium n'a pas provoqué une action plus forte que celle que l'on avait obtenue avec la peptone seule. Dans d'autres milieux contenant de la gélatine ou du nitrate de potassium, ou du sulfate d'ammonium ou de l'urée, l'action des enzymes était faible. On suppose que l'effet stimulant apparent de la peptone peut être dû à l'influence protectrice qu'elle exerce contre l'hydrolyse des enzymes.

CRACKING OF CHERRIES

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The amount of cracking in sweet cherries appears to be reduced by a Bordeaux (2-3-40) spray applied five to six weeks before picking. The amount of cracking on sprayed and unsprayed Bing cherries is shown in Table 1. A cherry grower on Vancouver Island, Mr. H. Thompson, was advised to spray with Bordeaux 2-3-40 on June 8th as a preventive against brown rot. Less than 4 per cent of the sprayed Bing cherries were cracked on July 9th, while the unsprayed cherry orchards in the same district had over 80 per cent. To obtain further proof that the Bordeaux spray had reduced cracking, Lambert cherry branches were sprayed and some left unsprayed. The percentage of cracking of the Lambert cherries after immersing in water for varying lengths of time, is shown in Table 2, samples 1, 2, 3 and 4. The samples 5 and 6, Table 2, were purchased ripe cherries and were sprayed in the laboratory and allowed to dry and then immersed in water. The number of cherries in each sample was about 100. The results shown in Table 2 indicate that Bordeaux is probably the factor responsible for reducing the cracking of cherries in the orchard of Mr. H. Thompson.

Table 1.—The amount of cracking of Bing cherries on Vancouver Island in 1936

Date	Name	Address	Treatment	Cracking
				%
July 9	H. Thompson	Royal Oak	Bordeaux 2-3-40 on June 8.	4.0
July 9	Experimental Farm	Saanichton	No treatment	90.0
July 9	Growers	Royal Oak	No treatment	80.0
July 14	H. Thompson	Royal Oak	Bordeaux 2-3-40 on June 8	25.0
July 14	Experimental Farm	Saanichton	No treatment	99.0
July 15	Growers	Vancouver Island Victoria to Nanaimo.	No treatment	90.0

Table 2.—The percentage of cracking of Lambert cherries sprayed with Bordeaux 2-3-40 and then immersed in water for various periods of time

Treatment	Sample						Average
	1	2	3	4	5	6	
Check, unsprayed	60.0	93.9	50.0	80.0	84.4	79.5	74.6
Bordeaux 2-3-40	19.2	64.5	12.1	28.5	65.2	55.3	40.8

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STOCK AND SCION RELATIONSHIPS IN SOME FOUR-YEAR-OLD APPLE TREES[1]

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[Received for publication April 15, 1937]

Horticultural literature abounds in reports on the behaviour and characteristics of the above-ground portion of apple trees, but until recently comparatively little attention has been devoted to the roots. During the winter of 1933–34 the root systems of 172 four-year-old apple trees were excavated and studied in their entirety. This paper is a report on the findings of this study, special attention being given to the inter-relationship of stock and scion, and to distribution of the root system.

REVIEW OF LITERATURE

The literature on stock-scion relationships was comprehensively reviewed in 1930 by Hatton (2) and Swarbrick (11). The former presented the evidence concerning influence of stock on scion, while the latter summarized the data indicating influence of scion on stock. From a study of these two reviews it is clear that stock and scion exert profound influences on each other and both play very important parts in determining the characteristics and behaviour of the resulting tree. The literature published subsequent to the above papers provides further information concerning stock and scion relationships. Vyvyan (13) reported that the distinctive characters of the root systems of two-year-old clonal stocks, Malling Nos. II and VI, remained approximately constant when worked with scions of their own variety or with Beauty of Bath or Grenadier whether the scions were root-grafted on to piece-roots or stem-grafted. Furthermore, the root systems of seedling stocks failed to take on distinctive characters when worked with Beauty of Bath and Grenadier respectively whether or not a length of stock stem was left below the graft union. Grenadier scions induced a root system with a smaller percentage of fibre than did Beauty of Bath. Evidence that this difference in percentage of fibre was due merely to differences in the size of the total root systems was presented by Amos and his associates (1) and also by Knight and Hoblyn (5). Additional evidence given by Hatton (3) indicates that clonal rootstocks when stem-worked influence the scion in amount of wood growth, habit of growth, height and spread of tree, stem girth, earliness and nature of blossom bud formation, time of blossoming, percentage flowers setting, amount, size, colour and quality of fruit, and degree of susceptibility to scab, mildew and leaf scorch. Some of these effects were also secured by working the scion varieties directly on piece-roots of clonal stocks. Furthermore, Knight (4) published data indicating that the root system is more important than the stock stem in determining scion performance.

On the other hand, Roberts (7) reaffirmed previous statements (6) that scion variety markedly regulates the root character of trees grown

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from piece-root grafts, but has much less influence on the root growth of budded trees. Furthermore, Roberts (7) found that in double-worked trees, some varieties, when used as intermediates, prevent the top scion from influencing the root, while other varieties permit such influence. Tukey and Brase (12) using doubleworked trees, concluded that the top scion had an appreciable influence on the growth and character of the rootstock in some cases. Most of the intermediates which they used were those classed by Roberts as medium or intermediate in their power of permitting scion influence to pass through them to the rootstock.

Roberts (8) also reported an experiment in which he grafted a number of English varieties, used by Hatton and his associates, on seedling roots. All but one gave the same root type. This may provide a clue to the somewhat contradictory results obtained by English and American investigators. They have been using different scion varieties and in many cases different rootstocks.

It seems probable that the relative influence of stock and scion on the resulting tree depends largely on the variety of the scion and nature of the stock used, and also to some extent on the method of propagation.

MATERIAL

The trees used in this study had four-year-old tops and five-year-old root systems at time of examination. They consisted of 14 different scion varieties worked on piece roots of one-year-old Canada Baldwin seedlings. The grafts were made in January 1930. First-piece roots, 4 inches long and three- to four-sixteenths of an inch in diameter, were grafted below the collar to 3-inch scions. Special care was taken to ensure uniformity in the size and condition of both roots and scion wood. Furthermore, all the grafting was done by one operator to ensure uniformity in the technique employed. As suggested by Roberts (6) the scion was cut so that the top bud was in line with the matched tongues of the graft.

After storage in damp peat for three months in a cool cellar the grafts were planted 6 inches apart in a nursery row. They were set upright with the top bud of the scion at ground level. All top growth made the first season was cut back to within 2 inches of ground level in the spring of 1931. This procedure resulted in strong, comparatively uniform, top growth during the summer of 1931. In November of that year the resulting trees were dug and careful records made of both root and top growth. The data secured have been incorporated in a paper by Rogers (10).

After being held over winter in a common storage cellar, the trees were replanted in the nursery in April 1932. They were set $2\frac{1}{2}$ feet apart in two adjacent rows 4 feet apart. At time of planting, the tops were cut back to 4 feet but the roots were left untrimmed. The trees were set with the original graft union about 10 inches below ground level. This procedure provided ample opportunity for scion roots to develop. When growth started, the tops were disbudded leaving only five buds on each tree to form branches.

Figure 1 shows the distribution of the 14 scion varieties in the nursery. In most cases all the trees of a scion variety were planted adjacent to one another, but with Wealthy and McIntosh the trees were planted in two separate groups, one in Row A and one in Row B. It may be well to

mention that Turner Red is a red colour strain of Delicious, and No. 227 is a variety introduced by the United States Department of Agriculture for rootstock purposes.

The soil in the nursery is a fertile silt loam underlaid with fine gravel at an average depth of 3 feet. It is of comparatively uniform composition and texture with the exception of about 50 feet at the east end where the gravel subsoil rises to within 2 feet of the surface. Irrigation was applied by the furrow method from the west end of the nursery. These factors provided less favorable growing conditions towards the east end of the rows and may have had some influence on the results reported in this paper.

The Northern Spy trees at the west end of Row A were used in developing the technique of excavation, weighing and recording. Accordingly, the records from these trees are not included in this paper.

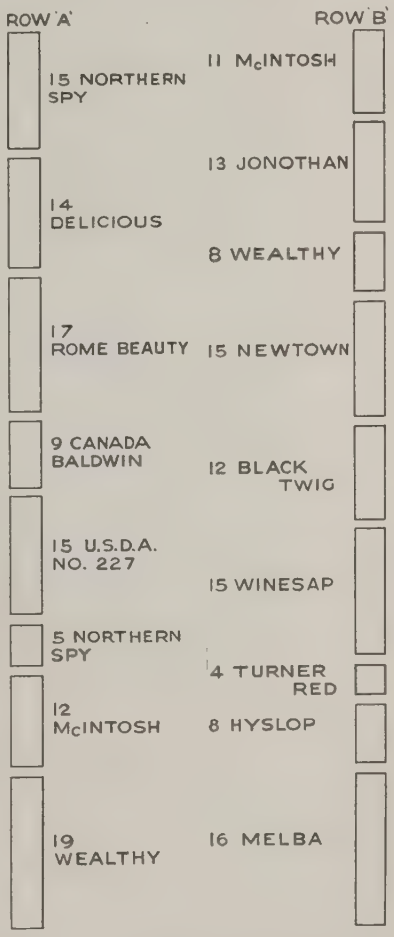

FIGURE 1. Plan showing number and variety and location of trees.

PROCEDURE

In November, 1933 the trees were excavated with their root systems entire in the following manner: A trench 4 feet deep was dug across the west end of the two rows about 2 feet from the first pair of trees. Working towards the trees, the earth was carefully removed with a shovel until the first roots were reached, when a fork was used to break the earth away from the finer roots. Before a tree was removed, it was first defoliated, labelled, and a notch cut in the stem at ground level.

As the trees were removed, they were taken into the laboratory and the roots washed immediately. They were allowed to dry overnight, and then weighed the following day. By this method the soil was removed and any water adhering to the roots was evaporated off without any appreciable loss of water from the plant itself. The nights were cool and evaporation was slow. Figure 2 illustrates the method of excavation used.

FIGURE 2. Showing Method of excavation.

In order to secure an accurate record of root distribution a method was devised for determining the weight of root located in each of six zones denoting depth and spread of the root system. Two 18-inch rings and a clamp were attached to a heavy iron stand. The rings and clamp were adjustable and were so arranged that the first ring was 12 inches below the top of the clamp and the second one 6 inches below the first one. The root system was set in this device, with the ground level mark on the trunk at the top of the clamp, and held in a central position by the clamp as shown in Figure 3. Care was taken to spread the roots in as near their original position as possible. Before weighing the main root system, all scion roots were removed and weighed separately. Then, starting with those roots outside the 18-inch ring, and below the 18-inch level, and continuing upward and outside the rings, roots were cut off in sections and weighed separately. Roots in the three zones inside the 18-inch ring were subsequently cut off and weighed separately. By this procedure, separate weight records were secured of those portions of the root system found in each of the six zones. The portion of the main "root" located between the original graft union and ground level was considered as part of the stem

FIGURE 3. Device used for determining root distribution.

and included in the weight of the top. This procedure was followed because, although this piece was located below ground level when the four-year-old trees were dug, it had developed from the scion and was thus in reality a portion of the stem.

The weight of the top part of each tree was also recorded.

RESULTS

Weights of Tops and Roots

The average weights of the root systems under each scion variety, together with the weights of the tree tops, composed of stems and branches, are shown in Table 1.

It is evident from the data presented in Table 1 and Figure 4 that there were marked differences in average weights of the Canada Baldwin seedling roots under the various scions. It should be noted here that when comparing the weights of tops and roots, scion roots have been included in the root weights, whereas, when considering the effect of scion variety on growth habit of the seedling stocks, these scion roots have been omitted. It is considered that this procedure is desirable because these scion roots are providing, as far as is known, water and minerals to the top

TABLE 1.—WEIGHTS OF TOPS AND ROOTS

Variety	Average weight of top	Average weight of root	Ratio top to root	Average weight of scion roots	Percentage trees with scion roots
	oz.	oz.	oz.	oz.	oz.
Delicious	43.7	20.2	2.06	0.94	29
Rome Beauty	53.1	18.5	2.32	1.50	100
Canada Baldwin	37.4	21.0	1.74	0.41	44
U.S.D.A. No. 227	91.5	36.0	2.18	7.57	100
Northern Spy	33.4	15.7	2.13	0.10	25
McIntosh A	34.9	21.9	1.57	0.10	70
Wealthy A	20.6	18.8	1.09	0.05	21
McIntosh B	25.2	13.9	1.77	0.10	70
Jonathan	31.6	22.0	1.43	0.12	64
Wealthy B	31.5	21.9	1.44	0.11	43
Newtown	33.2	14.4	2.13	1.02	80
Black Twig	54.7	22.6	2.35	0.64	64
Winesap	52.4	22.3	2.34	0.06	33
Turner Red	44.1	19.3	2.11	2.04	100
Hyslop	62.4	33.4	1.65	3.88	43
Melba	21.1	18.6	1.02	0.97	53

in the same way as the seedling roots, and therefore are an integral part of the root system of the tree. However, when considering the effect of the scion variety on the spread and depth of the seedling roots, the scion roots are obviously not a part of the seedling root system.

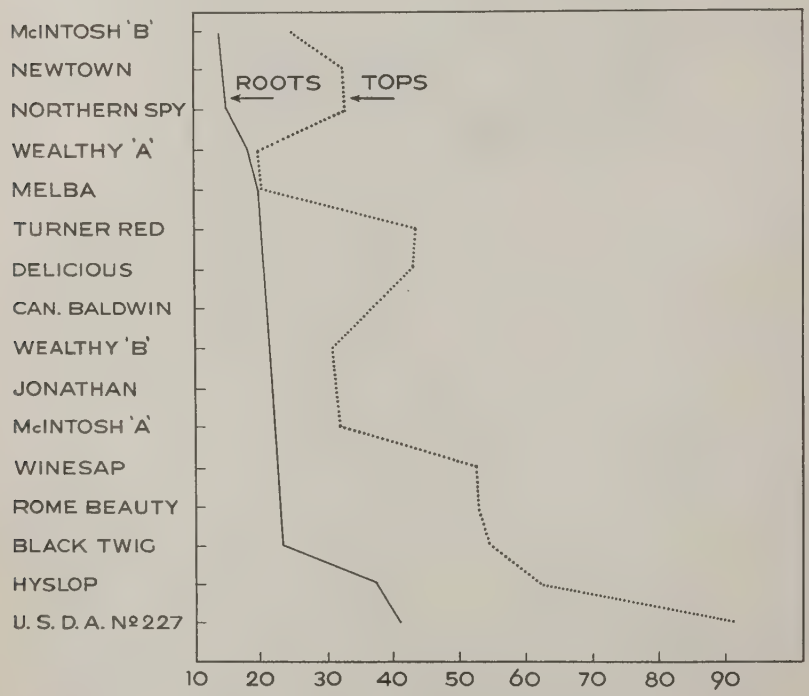

FIGURE 4. Graph showing average weight of tops and roots.

The data embodied in the last two columns of Table 1 indicate that the scion varieties differed greatly in their ability to send out roots from the portion of the stem planted below ground level. Rome Beauty, U.S.D.A. No. 227, and Turner Red, showed a marked tendency to produce scion roots, averaging 1.50, 7.57 and 2.04 ounces per tree respectively; whereas a comparatively small percentage of Delicious, Canada Baldwin Wealthy and Winesap developed scion roots. It seems highly probable that the large quantity of scion roots produced by U.S.D.A. No. 227 and Hyslop contributed materially to the comparatively large size attained by trees of these varieties. On the other hand, in spite of the fact that scion roots were produced by a large percentage of the trees of several other varieties, the actual weight of these roots was so small that it is doubtful whether they exerted any great influence on the weight of the tops.

From the data presented in Table 1, it is apparent that the ratio of top to root varied from 2.35 with Black Twig to 1.02 with Melba. The differences in these ratios may be due to variety or soil, or both. In support of this statement, attention is drawn to the data recorded with the two lots of McIntosh and Wealthy and one lot of Melba. The soil at the east end of the two rows of trees was shallower and received less irrigation water than the soil at the west end of the rows. McIntosh A and Wealthy A were located at the east end of row A, while the Melba trees were at the east end of row B. The other lots of McIntosh and Wealthy were at the west end of row B in deeper soil. Both the Melba and Wealthy A had a very low top-root ratio of 1.02 and 1.09 respectively. The one lot of McIntosh planted just west of the Wealthy A had a ratio of 1.57. As contrasted with these, the McIntosh in row B had a ratio of 1.77 and the Wealthy had a ratio of 1.44. Thus, the Wealthy had a lower ratio under both soil conditions than did the McIntosh. Apparently in this case both variety and soil influenced the top: root ratio. The shallow soil at the east end of the rows apparently inhibited top growth to a greater extent than root growth. This is in agreement with the findings of Rogers and Vyvyan (9) that in poor sandy soils more root was required to support a given amount of branch than in a loam soil.

Variability of Tops and Roots

Data concerning the variability of tops and roots are presented in Table 2.

TABLE 2.—VARIABILITY OF TOPS AND ROOTS

Variety	Coefficients of variability		Correlations between weights of tops and roots
	Tops	Roots	
Delicious	27.6	30.8	.927
Rome Beauty	27.3	32.8	.869
Canada Baldwin	16.5	18.2	.907
U.S.D.A. No. 227	32.1	31.4	.815
Northern Spy	22.9	30.5	.815
McIntosh A	41.5	38.0	.941
Wealthy A	43.7	46.1	.958
McIntosh B	46.2	42.7	.974
Jonathan	26.8	31.6	.918
Wealthy B	38.2	34.4	.961
Newtown	31.6	32.5	.852
Black Twig	11.9	15.2	.884
Winesap	14.5	20.5	.773
Turner Red	29.2	26.3	.967
Hyslop	20.9	19.7	.953
Melba	29.7	29.1	.806

The data presented in Table 2 show that the coefficients of variability of the tops *within* varieties varied from 11.9 with Black Twig to 46.2 with McIntosh. Similarly, the coefficients of variability of the roots varied from 15.2 under Black Twig scions to 46.1 under Wealthy scions. Some of this variability may have been due to small variations in condition of propagating material, grafting technique, planting procedure and soil conditions, but as special care was taken to minimize the variations in these factors, it is considered that the variability of the resulting trees was due largely to characteristics inherent in the seedling roots. It will be noted that there was a close similarity in the coefficients of variability of tops and roots within scion varieties. An explanation for this may be found in the very high correlations listed in the last column of the table.

The scion varieties may be classified in three groups having high, low and medium coefficients of variability. The group with high coefficients of variability includes the two lots of McIntosh and Wealthy, while the low group includes Black Twig, Winesap and Hyslop. The former produced comparatively small trees, whereas the latter produced comparatively large trees. Thus there is some evidence that vigorous scion varieties tended to produce more uniform trees, exerting a dominant influence over the variable seedling stocks. Conversely, there is some evidence that the weak growing varieties were dominated by seedling variation and consequently produced more variable trees.

It should be noted, however, that there was a good deal of variability in U.S.D.A. No. 227, Rome Beauty, Delicious and Turner Red in spite of the fact that these varieties produced comparatively large trees.

Statistical analysis of the variability of stock and scion *among* varieties reveals that there was more variation in the tops than in the roots. The coefficient of variability of the roots under the various scions was 31.1 and the coefficient of variability of the tops was 41.7. The comparatively high coefficient of variability of the tops is possibly due to the fact that they are different varieties and have different degrees of vigour, whereas the seedling roots had at least one parent in common.

Correlation values of the weights of top and root *within* varieties are shown in Table 2. In every case the correlation is high. This is evidence that when scions of the same variety were worked on seedlings the more vigorous seedling roots produced larger tops than did the less vigorous seedling roots. These results indicate a strong influence of stock on the vigour of the scion variety.

To secure information concerning the effect of scion on stock, the correlation of the weight of top and root *among* varieties was determined. This value was found to be 0.876. When the strong-growing scion varieties U.S.D.A. No. 227 and Hyslop were omitted from the calculations, the value was only 0.527. This fact indicates that the very vigorous scion varieties U.S.D.A. No. 227 and Hyslop imparted their vigour to the root-stocks on which they were worked. This strong quantitative effect of the two most vigorous scion varieties on root growth is shown graphically in Figure 4.

The data presented in Table 2 indicate that there was a strong quantitative influence of stock on the growth of all the scion varieties. On the other hand only the very vigorous scions, U.S.D.A. No. 227 and Hyslop induced a strong increase in root growth.

Distribution of Roots

The average weights of roots in the various zones are shown in Table 3.

TABLE 3.—AVERAGE WEIGHT OF ROOTS IN EACH ZONE

Variety	Within an 18-inch ring			Outside an 18-inch ring		
	0–12″	12–18″	Below 18″	0–12″	12–18″	Below 18″
	oz.	oz.	oz.	oz.	oz.	oz.
Delicious	13.2	2.8	0.6	0.6	1.6	1.4
Rome Beauty	12.4	1.6	0.6	1.0	1.6	1.3
Canada Baldwin	13.3	2.7	0.7	1.1	1.4	1.8
U.S.D.A. No. 227	23.1	2.5	0.7	2.6	3.1	4.0
Northern Spy	11.7	1.1	0.4	0.6	0.9	1.0
McIntosh A	13.9	2.6	1.1	0.5	1.3	2.5
Wealthy A	11.4	2.7	0.4	1.2	1.3	1.8
McIntosh B	7.2	3.4	1.1	0.4	0.6	1.2
Jonathan	12.3	4.8	1.0	0.6	1.5	1.8
Wealthy B	12.9	4.3	1.3	0.3	1.0	2.1
Newtown	8.5	2.4	0.6	0.4	1.4	1.1
Black Twig	14.6	2.9	0.7	1.6	1.6	1.2
Winesap	14.6	2.0	0.6	1.7	1.5	1.9
Turner Red	12.8	2.1	0.4	0.8	1.5	1.7
Hyslop	20.5	4.4	1.2	1.5	2.2	3.6
Melba	9.9	4.0	0.8	0.7	1.1	2.1
Average	13.27	2.9	0.76	0.97	1.47	1.9

From the data presented in Table 3 it is apparent that the weights of roots within an 18-inch ring tended to decrease towards the lower levels, whereas the weight outside this ring tended to increase. This held true for practically every variety. McIntosh B and Newtown produced the smallest total weight of roots, whereas U.S.D.A. No. 227 and Hyslop produced the greatest total weight of roots. Study of the data presented in Table 3 reveals that the additional root growth produced by the strong-growing scion varieties was fairly well distributed throughout the several zones. Nevertheless the percentage of roots in each zone was materially influenced by scion variety. This statement is substantiated by the data presented in Table 4.

TABLE 4.—AVERAGE PERCENTAGE OF ROOTS IN EACH ZONE

Variety	Within an 18-inch ring			Outside an 18-inch ring		
	0–12″	12–18″	Below 18″	0–12″	12–18″	Below 18″
	%	%	%	%	%	%
Delicious	65.5	13.9	2.9	2.9	7.9	6.9
Rome Beauty	67.2	8.6	3.2	5.4	8.6	7.0
Canada Baldwin	63.3	12.8	3.3	5.3	6.7	8.6
U.S.D.A. No. 227	64.2	6.9	1.9	7.3	8.6	11.1
Northern Spy	74.5	7.0	2.6	3.8	5.7	6.4
McIntosh A	63.5	11.8	5.1	2.3	5.9	11.4
Wealthy A	60.8	14.2	2.2	6.3	6.9	9.6
McIntosh B	52.2	24.4	7.9	2.7	4.2	8.6
Jonathan	55.9	21.9	4.6	2.7	6.8	8.2
Wealthy B	58.9	19.9	6.1	1.5	4.7	8.9
Newtown	59.3	16.6	4.2	2.8	9.6	7.5
Black Twig	64.6	12.9	3.2	7.0	7.0	5.3
Winesap	65.5	8.9	2.8	7.6	6.7	8.5
Turner Red	66.5	10.9	2.1	4.2	7.7	8.8
Hyslop	61.4	13.1	3.6	4.5	6.6	10.8
Melba	63.3	21.5	4.3	3.7	5.9	11.3
Average	62.29	14.08	3.75	4.37	6.84	8.68

In Table 5 the average weights of roots outside an 18-inch ring are expressed in ounces and also as percentages of the average root weight of each variety. Similarly, the average weights of roots extending below a depth of 18 inches are expressed in ounces and as percentages of the average root weight of each variety. It will be noted that the strong-growing varieties, U.S.D.A. No. 227 and Hyslop, each produced a greater weight of roots in the area outside an 18-inch ring and also in the area below 18 inches in depth than did any other variety. From the percentage figures, however, it is apparent that McIntosh B, the variety with the smallest average root weight, produced a greater proportion of root below 18 inches in depth than did any other variety.

TABLE 5.—COMPARISON OF WEIGHT AND PERCENTAGE ROOT DISTRIBUTION

Variety	Total weight of Roots	Roots outside 18-inch ring		Roots below 18-inch depth	
		Weight	Per cent	Weight	Per cent
	oz.	oz.	%	oz.	%
Delicious	20.2	3.6	17.8	2.0	9.9
Rome Beauty	18.5	3.9	21.0	1.9	10.2
Canada Baldwin	21.0	4.3	20.5	2.5	11.9
U.S.D.A. No. 227	36.0	9.7	27.0	4.7	13.0
Northern Spy	15.7	2.5	15.9	1.4	9.0
McIntosh A	21.9	4.3	19.6	3.6	16.4
Wealthy A	18.8	4.3	22.8	2.2	11.7
McIntosh B	13.9	2.2	15.8	2.3	16.5
Jonathan	22.0	3.9	17.7	2.8	12.8
Wealthy B	21.9	3.4	15.5	3.4	15.5
Newtown	14.4	2.9	20.1	1.7	11.8
Black Twig	22.6	4.4	19.4	1.9	8.4
Winesap	22.3	5.1	22.8	2.5	11.2
Turner Red	19.3	4.0	20.7	2.1	10.9
Hyslop	33.4	7.3	21.8	4.8	14.4
Melba	18.6	3.9	20.9	2.9	15.6
Average	21.28	4.36	19.96	2.67	12.45

Statistical analysis of the weight records from which the data in Tables 3, 4 and 5 were compiled revealed that there was a good deal of variation in root habit in trees of the same scion variety. Nevertheless, there were a number of significant differences in percentage root distribution between trees of the different varieties. For instance, U.S.D.A. No. 227 induced a significantly greater percentage root growth outside an 18-inch ring than did Wealthy A, Wealthy B, Jonathan, Delicious, McIntosh A, McIntosh B, and Black Twig. Then again, Winesap, Wealthy A, Black Twig, U.S.D.A. No. 227, Rome Beauty and Delicious each produced a significantly greater percentage of root in the top foot of soil than did McIntosh B, Jonathan and Wealthy B. Furthermore, McIntosh A, McIntosh B and Wealthy B each produced a significantly greater percentage of roots below 18 inches in depth than did Black Twig, Delicious, Rome Beauty and Winesap.

In brief, it may be stated that the various scion varieties tended to induce root systems with the characteristics indicated below: Delicious,

Rome Beauty, Black Twig, Winesap and Turner Red, shallow and medium spreading; Northern Spy, shallow and compact; Canada Baldwin, Wealthy A, Jonathan, Newtown, and Hyslop, medium depth and spread; U.S.D.A. No. 227, medium depth and wide spreading; McIntosh A and Melba, deep and medium spreading; McIntosh B and Wealthy B, deep and compact.

It will be noted that the McIntosh trees in Row A had a tendency to produce comparatively spreading deep root systems, whereas McIntosh trees in Row B tended to produce compact deep root systems. Furthermore, the Wealthy trees in Row A tended to produce roots of medium depth and spread whereas those in Row B tended to produce compact deep root systems. These findings suggest that soil conditions exerted some influence on the root habit of the trees used in this experiment. However, reference to the planting plan shown in Figure 1, reveals that scion varieties producing root systems of the various types were well distributed over the planting area.

SUMMARY

The root systems of 172 four-year-old apple trees were excavated. These trees represented 14 scion varieties which had been piece-root grafted on one-year-old seedlings of Canada Baldwin. The root system of each tree was divided into six zones denoting depth and spread from the original piece root. The root growth in each zone was weighed separately. The more important findings may be briefly summarized as follows:

1. There were significant differences in the average weights of the Canada Baldwin seedling roots under the various scion varieties.

2. The varieties U.S.D.A. No. 227 and Hyslop, which developed large tops and a comparatively large quantity of scion roots, induced exceptionally vigorous growth in the seedling roots on which they were grafted.

3. Variability inherent in the seedling roots was reflected in the growth of the scion varieties grafted on them.

4. Scion varieties differed in their ability to overcome variation in the seedling roots on which they were grafted.

5. Scion varieties exerted a significant influence on the spread and depth of root growth made by the seedling stocks on which they were grafted.

ACKNOWLEDGMENTS

Acknowledgment is due to Messrs. H. Smith and D. J. Strachan for assistance with the tedious operation of excavating and weighing the roots; and to Mr. J. E. Britton for taking the photographs presented in Figures 2 and 3.

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Résumé

Rapports entre le sujet et le greffon dans quelques pommiers de quatre ans. R. C. Palmer et F. N. Hewetson, Station expérimentale fédérale, Summerland, C.-B.

Les racines de 172 pommiers âgés de quatre ans ont été sorties de terre. Ces arbres représentaient 14 variétés de greffons, greffés sur racines, sur sauvageons d'un an de "Canada Baldwin." Les racines de chaque arbre ont été divisées en six zones, dénotant la profondeur et le développement latéral du morceau original de racine. L'ensemble des racines de chaque zone a été pesé séparément. Les constatations les plus importantes peuvent se resumer sommairement comme suit: Il y avait des différences significatives entre les poids moyens des racines de sauvageons Canada Baldwin, sous les différentes variétés qui avaient servi de greffons. Les variétés U.S.D.A. nº. 227 et Hyslop, qui avaient développé de larges cimes et une quantité relativement forte de racines, ont provoqué une pousse exceptionnellement vigoureuse dans les racines du sauvageon sur lesquelles elles avaient été greffées. La variation inhérente dans les racines des sauvageons se réfléchissait dans la pousse des variétés de greffons greffés sur elles. Les variétés de greffons n'avaient pas toute la même aptitude à surmonter la variation que présentaient les racines du sauvageon sur lesquelles elles étaient greffées. Elles ont exercé une influence significative sur le développement et la profondeur de la pousse des racines faite par les sujets sauvageons sur lesquels elles étaient greffées.

FIELD STUDIES OF APPLE TREE GROWTH AND FRUITING

I. SAMPLING AND MEASURING TERMINAL SHOOTS[1]

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This is the first paper of a series of five which it is proposed to present, covering field studies of apple tree growth and fruiting made in a 23-acre orchard at Kelowna, British Columbia. The trees in this orchard consisted of McIntosh, Jonathan, Delicious, Newtown, Wealthy and Duchess. In the spring of 1931, when the work was started, the original planting was 19 years old, though there had been quite a number of replacements made at various times. During the past six years, most of the trees have been affected to some extent with drought spot and its related disorders, which have been shown to be due to a lack of boron (11). For the most part, however, they have been making comparatively good vegetative growth. The soil is light and shallow, being underlaid by gravel at from $1\frac{1}{2}$ to 3 feet. The cover crop has consisted of a mixture of alfalfa, sweet clover, grasses and weeds.

In the spring of 1931, a series of field plot treatments was initiated in this orchard, for the purpose of studying the effects of these treatments on physiological disorders, on tree growth, and on fruiting of the apple. During the past six years, a large number of records have been obtained. These records have served both to ascertain the effects of plot treatment and to supply material for the study of correlations between the different external characteristics of the tree. Some of the findings with respect to physiological disorders have been published by McLarty (11), and by McLarty, Wilcox and Woodbridge (12). It is the purpose of this series of papers to present only those results that have to do with the growth and fruiting of the trees. This present paper deals with studies of the sampling and measuring of terminal shoots. The first section embodies a report on an investigation into the sampling of terminals; and the second section deals with a series of studies on the measurement of the terminal diameter. The actual use to which the measurements of terminal length or terminal diameter may be put will be discussed in the third article of the series.

REVIEW OF LITERATURE

Sampling the Terminals on Bearing Trees

It has been a common practice with young trees to measure all the twigs on the tree, or at least to measure all the terminal shoots. As the tree grows, however, the measurement of all the terminals becomes impracticable. Hoblyn (7), Vyvyan (13) and their co-workers have developed very efficient methods of recording and classifying all the growths on a tree. As the trees have become larger, however, they have been forced either to limit the number of trees recorded in detail or to resort to sampling methods. Hoblyn (7) found that the average shoot length could be estimated fairly

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accurately from the prunings removed in the dormant season. Even with one-year-old peach trees, Blake and Hervey (2) found it advisable to develop a method of sampling the twigs. Anthony (1) obtained his annual record of branch elongation on apple trees by the following method: On the lower half of the tree, the terminals were studied until the upper and lower limits of about the middle 75 per cent by length were determined; the same was done on the upper half of the tree; and the four figures thus obtained were averaged to give a single figure representing the tree growth. Cummings, Jenkins and Dunning (6) sampled the twigs of apple trees by taking 25 in the upper half of the tree and 25 in the lower half. They found that the average twig growth was always longer in the upper half than in the lower half. The method used by Overley and Overholser on apple trees was as follows: "The new season's growth was measured on approximately 20 terminals per tree, around the perimeter of the tree, 6 to 15 feet from the ground. Terminals selected were on large branches or main leaders that had not been pruned for three preceding years or more, thus eliminating growth stimulated by pruning. Shoots growing horizontally, or not exceeding a 45-degree angle in growth from the main tree were selected. By this method, the excessively vegetative upright growths, and those whose growth was restricted by a too drooping position were eliminated." (11). Bradford and Joley (4) studied different methods of characterizing the growth of apple trees. They concluded that if the total weight of the one-year-old shoots is to be accepted as the criterion of growth, then the measurement of terminal length by itself is not sufficient. It is necessary in addition to take into account the increasing ratio of weight to length as the length increases. From the measurements of Red Canada prunings, they constructed a graduated scale to use in converting lengths into weight. Other investigators (3, 5, 8) report the use of 10, 20, 25 or more terminals from around the outside of the tree to represent the average for the tree as a whole.

Measuring the Diameter of the Terminal

Roberts (12) working with young apple trees, compared the structure of terminal shoots with their chemical composition and with their production of fruit buds. He found that measuring the diameter of the shoot near its tip gave an indication of the quality of growth in contrast to the length as an indication of the quantity of growth. Overley and Overholser (11) measured the terminal diameter first at the base of the shoot, then later at the centre of the shoot. They found a very definite correlation between terminal length and terminal diameter.

EXPERIMENTAL

Procedure

A. Sampling the Terminals

In the fall of 1931, an investigation was conducted into methods of sampling the terminal shoots of apple trees for the purpose of determining their average length and diameter. Twenty trees were chosen for the preliminary study, consisting of four trees of different ages and different conditions of growth in each of the following varieties: McIntosh, Jonathan, Delicious, Duchess and Wealthy. In each case, the length and diameter were measured of every terminal that was the last of at least five years of

successive terminal growth. They were divided into twelve classes, in accordance with their position on the tree and with their angle of growth. The average for each class was then compared with the average for the tree as a whole, and from this comparison an attempt was made to devise a satisfactory method for the sampling of terminals. Finally, field tests were made to determine the accuracy of that method of sampling which appeared to be the most promising. All the field records in these investigations were taken during the dormant season.

Results

Some of the findings from this investigation were as follows:

1. There was a wide variation in length from tree to tree. The lowest average among the twenty trees was 6.3 cm., and the highest was 30.2 cm. There was likewise a wide variation on the same tree.

2. The more upright the direction of growth of the terminal, the greater was its length.

3. Those terminals growing at any one angle with the horizontal averaged a little longer at the top of the tree than at the bottom. The difference was however not statistically significant.

4. The average length of all the terminals at the top of the tree was quite definitely greater than that of those at the bottom. This was due to the fact that there were more terminals at the top with an upright direction of growth than there were at the bottom.

5. There was a great deal of variability between trees and between varieties in the percentage of terminals growing at any one angle.

6. There was a high correlation between the length of the terminal and its diameter.

7. Those terminals that were open to the sunlight had a greater diameter in proportion to their length than had those that were partly shaded.

A typical example of the effects of height and of angle of growth is given in Table 1.

TABLE 1.—EFFECTS OF HEIGHT AND ANGLE ON TERMINAL LENGTH
(Tree No. Z29, a Delicious)

Angle of growth	Height of tree			Average*
	Top	Centre	Bottom	
	cm.	cm.	cm.	cm.
Vertical†	35.5	33.6	—	34.8
Oblique	23.3	22.4	20.3	22.3
Horizontal	20.1	20.8	15.5	20.2
Downwards	11.8	12.2	12.8	12.2
Average*	25.4	21.7	17.0	22.4

* The averages at the right hand side and at the bottom are weighted by the number of terminals.
† The actual class limits were determined by the angle with the horizontal, as follows: vertical, 75 to 90 degrees; oblique, 15 to 75 degrees; horizontal, 0 to 15 degrees.

A comparison of the average for each of the four angles of growth with the average for the tree as a whole showed that no one angle could be used satisfactorily to represent all trees. On young trees or heavily pruned

trees, the proportion of uprights was very high; while on older, heavily bearing trees, the proportion of uprights was low. The reverse was true with the horizontals and those pointing downwards. Thus the average of neither the most upright nor the least upright of the terminals could be used to represent the average of the tree as a whole with any degree of accuracy. The most satisfactory angle was the oblique. The terminals at this angle showed less variability from tree to tree in their percentage of the total than did those at any other angle. Their average, likewise, was in almost every case very close to that of all the terminals.

As a check on the use of a sample of the obliques to represent the tree as a whole, ten oblique terminal shoots were chosen at random around the outside perimeter of each of the twenty trees, and their lengths measured. The averages thus obtained were compared both with the averages of all the obliques and with the averages of all the terminals on the respective trees. Where the average of all the terminals was used as the standard of comparison, the probable error was ± 1.20 cm. Where the average of the obliques was used as the standard, the probable error was ± 0.90 cm. The procedure was then repeated with twenty terminals to the tree, the respective probable errors being ± 0.99 cm. and ± 0.68 cm. Various "short cut" methods were also tried—such for example as selecting the longest and shortest obliques on two sides of the tree, or the longest uprights and the shortest horizontals—but the results were not satisfactory.

Discussion

The shoot growth has been quite commonly used as a measurement of that condition of the tree that is termed vigour, or more specifically, vegetative vigour. Various methods of measuring the annual shoot growth have been used. In some cases, the total shoot growth has been recorded (7). In most cases, however, samples of the terminals have been measured or estimated, and their average used to represent the condition of the tree with respect to vigour (1, 2, 3, 5, 6, 8, 11). It has appeared to the writer that since the number of shoots on a tree depends to a large extent on the size of the tree, the total shoot growth on one tree cannot be compared to that on another tree unless these trees are of the same size or age. Accordingly, the method of measuring all the shoots on the tree has been disregarded, and methods of sampling have been dealt with instead. The type of terminal that has been found the most satisfactory for sampling has been that growing at an oblique angle.

The preference for the use of oblique terminals does not depend entirely on their mathematical accuracy. Other factors are also worthy of mention. For example, the obliques do not tend to be sucker-like in nature, as the uprights often do. They do not bear terminal fruit buds as frequently as do the horizontals; hence it is easier to select the required number for the sample. And they are more likely than any other type to terminate the scaffold or other main limbs. A difficulty sometimes encountered is that some of the terminals that have made their linear growth in the oblique position have later been pulled down by the weight of the crop to the horizontal position. In such a case, it becomes necessary for the operator to make some allowance for the effect of the weight of the crop by including some of the horizontals in the sample.

The question arises as to whether the sample of terminals selected should be such as will approximate the average of all the terminals on the tree, or whether it should represent a condition of growth. If the latter is to be preferred, then the standard of comparison should be, not the average of all types of terminals, but rather the average of some particular type. Since the length of a terminal is affected greatly by its angle of growth, it is obvious that the uprights on one tree do not represent the same condition of growth as do the obliques or the horizontals of the same length on another tree. On the basis of growth condition, it is quite unfair to use the average of all the terminals to represent trees on which the percentages of uprights, obliques and horizontals show considerable variation. And this holds true not only from tree to tree, but also from year to year on the same tree. For comparison purposes only, any one type of terminal adhered to consistently should prove satisfactory; but since the obliques approximate more closely the actual tree average than does any other type and since they are more commonly found than any other type on the main limbs around the perimeter of the tree, their use is to be preferred. The average of a sample of obliques should represent the growth condition of a tree more accurately even than it does the average terminal growth.

Method adopted

During the past six years, the terminal growth in the Kelowna Project orchard has been recorded from samples chosen in the following manner:

Starting at one of the four points of the compass, and moving to the left, the operator selects the first five terminals that fulfil the following requirements: each terminal must be preceded by at least three years of successive terminal growth; it must be well out in the sunlight around the perimenter of the tree; and it must either be at an angle of 15 to 75 degrees from the horizontal or show some evidence of having been at that angle while the linear growth was being made earlier in the season. This means that the choice of terminals requires the exercise of a certain amount of judgment, though on the whole the operation is automatic. Five more terminals are then selected in similar manner at each of the other three points of the compass, making a total of twenty. On small trees, the total is reduced to ten. Where for any reason the required number of terminals of the desirable type have not been available, it has been found preferable to use the lesser number available rather than to make up the total with terminals of another type. To assist in reaching for suitable limbs, the operator carries a four-foot stick with a hook on the end.

This method has been tested by the comparison of duplicate samples, and in various other ways, and appears to be quite reliable. Moreover, the method has practically eliminated the personal factor to the extent that different operators have obtained the same or practically the same results on the same trees. It might be noted that this method is very similar to that of Overley and Overholser (11).

B. The Best Position at Which to Measure the Diameter of the Terminal

Procedure

When the original records were taken on the twenty trees noted above, the terminal diameter was measured at approximately one inch from the base. It was found, however, that the variation in diameter at this point

was so great that the results were unsatisfactory. Accordingly, other possible positions of taking the measurement were investigated. On a number of trees, the terminal lengths were recorded, together with the diameters at the base, at one-half inch from the base, at one inch from the base, at the centre, and at approximately one inch from the tip. Wherever the shoot was noticeably flattened at the point measured, the least diameter at that point was the one recorded. At the centre of the terminal, and at approximately one inch from the tip, the measurement was taken between the buds. The lengths were measured in centimetres, to the nearest tenth, and the diameters in inches, to the nearest 1/128th. The coefficients of correlation were then calculated for each tree between the terminal length and each of the respective diameters.

During the past six years, further observations were made of the value of the various possible positions for measuring the diameter; and this past fall (1936) another systematic investigation was conducted. It appeared that the diameter was affected by a number of factors, chief among which were the length of the terminal and those factors which influence the size of the annual ring of wood over the tree as a whole. To check upon this, twenty oblique terminals were first selected on each of a number of McIntosh trees, and were measured for length, diameter at the base, diameter at the centre, and diameter at one inch from the tip. The length : diameter correlations were determined. The same measurements were then taken on 50 McIntosh trees, and correlations made between the length and diameter averages; also between the length averages and the increases in trunk circumference. From these various calculations, an attempt has been made to determine which position of recording the terminal diameter is to be preferred.

Results

The records taken in the fall of 1931 gave high correlations between the length and all five of the diameters. Those at the base, at one-half inch from the hase, and at one inch from the base were however somewhat higher than the other two. Of these three, that at the base was found by replicate measurements to give the least error in the process of recording. Accordingly, it was the method adopted for use at that time. It has however since been found that with some varieties the measurement at the base is not always reliable: after the heavy-bearing year of a biennially-bearing Jonathan tree, for example, the diameter may decrease very rapidly for the first two millimetres or so from the base and it is then difficult to obtain an accurate measurement.

In the 1936 investigation, high correlations were found between the terminal length and each of the three diameters (base, centre, and one inch from tip), when the terminals were all of the same type and from the same tree. The correlation of the length with the diameter at the base was consistently the highest, and that at the tip the lowest. The differences were however not great. Tree number 05, for example—a typical tree—gave the following correlations:

$r_{Lx} = +0.853$ $r_{Ly} = +0.815$ $r_{Lz} = +0.716$

where L = terminal length,
x = terminal diameter at base,
y = terminal diameter at centre,
and z = terminal diameter at one inch from tip.

The correlations between the length and the square of the diameter showed a somewhat greater spread:

$$r_{Lz^2} = +0.932 \qquad r_{Ly^2} = +0.807 \qquad r_{Lz^2} = +0.690$$

It appears from these results that the diameter of the terminal bore a close relation to the length, but that this relationship became a little less definite in the order of base, centre, and tip.

The tree averages from the terminals on the 50 McIntosh trees indicated a similar tendency; though in this case the correlations were lower and showed a much greater spread:

$$r_{Lx} = +0.631 \qquad r_{Ly} = +0.121 \qquad r_{Lz} = +0.019$$

The lack of significance in the last two of these correlations was presumably due to differential factors that were not encountered when the terminals were all taken on the one tree. Good correlations were however found between the increase in trunk circumference (I) and each of the three diameters:

$$r_{Ix} = +0.558 \qquad r_{Iy} = +0.416 \qquad r_{Iz} = +0.311.$$

This relationship, it would appear, also decreased from the base to the tip, though the rate of decrease was much less than that between the terminal length and the diameter.

One of those factors found to exert a disturbing influence on the above relationships was the general vigour of the tree as a whole. A partial measure of this influence was obtained from the correlation between the average terminal length and the increase in trunk circumference:

$$r_{LI} = +0.380.$$

With this correlation to assist, the effects of the terminal length could be eliminated from the above correlations:

$$r_{Ix \cdot L} = +0.624 \qquad r_{Iy \cdot L} = +0.438 \qquad r_{Iy \cdot L} = +0.331.$$

It would appear from these data that the terminal diameter at the base was affected to a large extent both by the terminal length and by those factors that influence the laying down of the annual ring on the trunk. At one inch from the tip of the terminal, both effects were lessened, but the former much more than the latter. The diameter at the centre was more like that at the tip than that at the base.

In an attempt to evaluate further some of the factors involved in the above correlations, a close study was made of the data entering into them. It was found that a change from tree to tree in the increase in trunk diameter was accompanied by a somewhat greater change in the terminal diameter at the base than in the diameter at the centre or tip. The slopes of the lines of trend are depicted graphically in Figure 1. An examination of the scatter diagrams used in these studies showed that the greater spread in the coefficients of correlation in comparison with the slopes of the lines of trend was due chiefly to the fact that the deviations of the plotted points away from these lines of trend were much greater at the centre and tip than at the base. One of the factors entering into this greater variability was undoubtedly the increase in the error of measurement at the centre and tip.

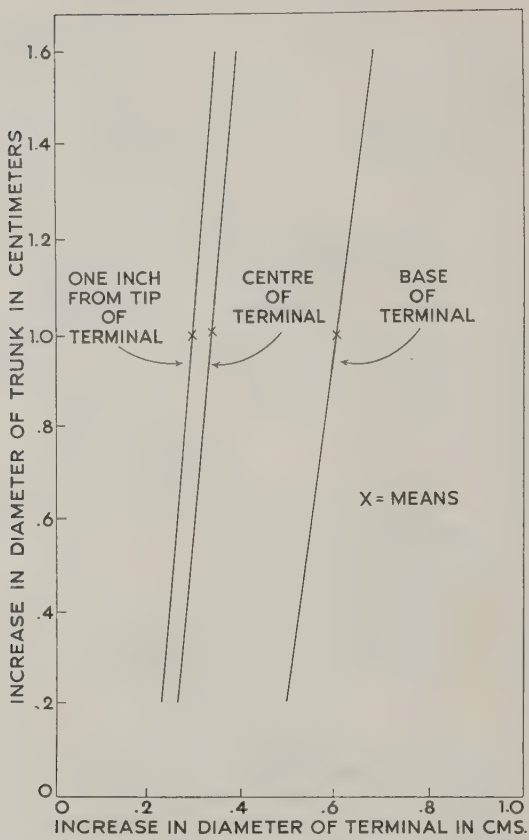

FIGURE 1. Slopes of lines of trend obtained by plotting the increase in the trunk diameter against the diameter of the terminal at the base, at the centre, and at one inch from the tip. The data on which these slopes are based are from measurements taken on fifty check-plot McIntosh trees in the fall of 1936.

Discussion

The main conclusions from these studies would seem to be: first, that the terminal diameter was influenced most at the base both by the terminal length and by those factors associated with the increase in trunk circumference; second, that at the centre and tip the former of these influences had lessened much more than the latter; and third, that the chances of errors in recording were much greater at the centre and tip than at the base. This last was due to the fact that at any point on the shoot except at the base, there is continual variation in the diameter. On the other hand, the measurement at the base was frequently found to be affected by the diameter of the shoot of the previous year, though this was more true with certain other varieties than with the McIntosh. By the method of selecting the terminals, none were used in these studies that had made secondary growth, so that the effects of secondary growth on the diameter at the tip did not enter into the problem.

The question arises as to just what is the real purpose of measuring the terminal diameter. It has been pointed out by Roberts (12) and others that the diameter of the terminal in relation to its length is proportionately representative of the diameter of the new layer of wood and bark laid down over the tree as a whole, and that this in turn is of special significance as an indication of those particular internal conditions in the tree that have to do with the formation of fruit buds. Terminal length, terminal diameter, and the relationship between them accordingly supply a good deal more information than terminal length alone. It follows though that to supply the required information, it would be desirable to measure the terminal diameter in such a manner that the measurement is affected as little as possible by the terminal length, and as much as possible by those factors that influence the size of the new layer of wood and bark. Another measurement of this last is the increase in trunk circumference. It appears logical, then, to conclude that the position for taking the terminal diameter that should be used is the one that is influenced the least by the terminal length and that bears the closest relationship to the increase in trunk circumference. It would appear that no one position is entirely satisfactory in this respect. In this investigation, the position that has most nearly met the various requirements has been approximately one inch from the tip. The value of the terminal diameter as a measurement of tree vigour and tree condition will be dealt with again in the third paper of this series.

Method Adopted

The method now used by the writer is to measure the terminal diameter at 1 to $1\frac{1}{2}$ inches from the tip. The narrowest point is chosen between two buds, and the calipers are turned so as to measure the narrowest diameter at that point. Care is taken to use only normal-type shoots: for example, none are chosen which have made a secondary growth, or which for any reason have not matured reasonably well at the tip.

SUMMARY

Investigations were conducted into the sampling of terminal shoots, and into the measurement of the diameter of the terminal. The principal findings were as follows:

1. The more upright the direction of the terminal growth, the greater was its length. Those terminals growing at any one angle with the horizontal averaged a little longer at the top of the tree than at the bottom, though the difference was not significant. A sample of terminals growing at an angle with the horizontal of 15 to 75 degrees proved the most satisfactory type of sample of those studied and tested.

2. The correlation between the terminal length and terminal diameter decreased as the position of recording the diameter was varied from the base to the tip. The correlation between the increase in trunk circumference and the terminal diameter decreased in the same order, though the rate of decrease was much less. It is suggested that if it is desired to eliminate from the records of terminal diameter the effects of terminal length, the most satisfactory position at which to take the measurement is close to the tip.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the helpful suggestions of Dr. H. R. McLarty, Officer-in-charge of the Dominion Laboratory of Plant Pathology at Summerland, and of Mr. R. C. Palmer, Superintendent of the Dominion Experimental Station, Summerland, both in respect to the studies of tree records and to the preparation of this paper.

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Résumé

Études de la végétation et de la fructification des pommiers dans le verger. I. Comparaison et mesurage des tiges terminales. J. C. Wilcox, Station expérimentale fédérale, Summerland, C.-B.

Ces recherches portent sur la comparaison des tiges terminales et sur la mesure du diamètre de la tige terminale. Les constatations principales sont les suivantes: Plus la direction de la pousse terminale est droite, plus cette pousse est longue. Les tiges terminales poussant en formant un angle avec l'horizontale sont en moyenne un peu plus longues au sommet de l'arbre qu'au pied, mais la différence n'est pas significative. Un échantillon de tiges terminales poussant à un angle de 15 à 75 degrés avec l'horizontale était le type le plus satisfaisant d'échantillons de tous ceux qui ont été étudiés et essayés. La corrélation entre la longueur et le diamètre de la tige terminale diminue à mesure que la prise du diamètre varie, à partir de la base jusqu'au sommet. Cette corrélation entre l'augmentation dans le circonférence du tronc et le diamètre terminal diminue dans le même ordre, mais le taux de diminution est bien inférieur. L'auteur croit que si l'on veut éliminer des chiffres du diamètre terminal l'effet de la longueur terminale, l'endroit le plus satisfaisant auquel on peut prendre les mesures est près de la pointe.

FIELD STUDIES OF APPLE TREE GROWTH AND FRUITING

II. CORRELATIONS BETWEEN GROWTH AND FRUITING[1]

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As noted in the first paper of this series, field plot treatments were started in an apple orchard at Kelowna, B.C. in the spring of 1931, for the purpose of studying the effects of these treatments on physiological disorders, on tree growth, and on fruiting ability. When the various plots were first laid out, it was found impossible to arrange them in such a manner that the trees in any one plot would be exactly comparable to those in all the other plots with which they were to be compared. It was impossible to avoid differences in variety, in size of tree, in soil, in cover crop, in tree vigour, and in bearing habits. It became evident, then, that if the results obtained from differential treatments were to be interpreted correctly, it would be necessary to consider each tree a separate unit and to study the changes induced in it throughout the course of the experiments. It became evident further that in order to interpret correctly those annual measurements which would be used as indications of treatment effects, it would be necessary to gain as complete an understanding as possible of the relationships between these various measurements: the relationships not only between trees, but also between those measurements taken on the individual tree. In order to evaluate these relationships, the records taken during the past six years have been studied in some detail. The general findings are reported in this paper.

REVIEW OF LITERATURE

A large number of papers have appeared dealing with the relationships between the different parts of the individual tree, and it would be beyond the scope of this report to attempt a complete review of them. It is desired, however, to mention some of the more representative findings that deal with the same phases of the subject covered in this paper. They will be confined for the most part to actual correlations between the measurements and counts recorded on apple trees.

Effect of Size of Tree on Vigour

It appears to have been quite a common experience that as the tree gets larger, it becomes less vigorous. Gardner, Bradford and Hooker (10) and Chandler (4), in their respective textbooks on fruit growing, point out that this tendency is quite characteristic of fruit trees.

Correlations between Measurements of Vigour

The measurements that are dealt with under this heading are those taken during the dormant season only. Partridge (25) has found that where trees are bearing biennially, they increase in trunk circumference more in the off year than in the on year. Roberts (28) and Finch (8)

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have corroborated this finding by anatomical studies. Biennially-bearing trees might accordingly be expected to show a negative correlation between the increase in trunk circumference one year and the same the following year. Mack (19) has reported that he found the terminal growth to be longer as a rule in the on year than in the off year. Roberts (28) has obtained similar results; while Hofmann (16) has found that the reverse sometimes holds true. Overley and Overholser (24) have obtained a high positive correlation between terminal length and terminal diameter. Roberts (28) has found the terminal diameter to be less in the on year, when variations in length are taken into consideration. Hofmann (16), however, has found the terminal diameter to be correlated directly with the yield of the following year, when no consideration is taken of the effect of variations in length. It would appear that the findings with respect to terminal length and terminal diameter have not been entirely consistent. It has been shown by Harvey (13), Proebsting (26), and Roberts (28) that the linear growth of the terminal is made largely at the expense of stored-up food, and therefore is affected by the growth and fruiting conditions of the year before. A large amount of work has been reported on spur growth and its relationship to other parts of the tree. Since however this phase of the subject is not being dealt with in this present report, it will be omitted from the review of literature.

Correlations between Bloom and Set of Fruit

Biennial bearing of apples has been noted by a large number of investigators. Very few, however, appear to have calculated the actual correlations, in the different varieties and under the different conditions encountered, between the bloom or crop of one year and that of the following year. Degman, Furr and Magness (7), and Magness, Degman and Furr (22), have presented distribution charts showing a negative correlation between the fruits per 100-cm.^{2} area of trunk cross-section one year and the percentage bloom of the following year. It is obvious that where trees are bearing biennially the percentage bloom of any one year will be correlated inversely with the same of the following year. Ruth and Baker (29) have found a highly significant positive correlation between the percentage of bloom and the yield of the same year. Limbs with a low percentage of bloom have been noted by Heinicke (14) to hold a greater proportion of the fruits after the June drop than did limbs with a high percentage of bloom. The same has been reported for whole trees by Chandler and Heinicke (5).

Correlations between Growth and Fruiting

As noted above, it has been found that there is a tendency for biennially-bearing trees to have a larger increase in trunk circumference and a shorter terminal growth in the off year than in the on year. Swarbrick (31) has found that the more rapidly the shoots stop their linear growth in the summer, the higher is the percentage bloom of the following year. This has been confirmed by Warne and Wallace (32), who reported high negative correlations between the rate of shoot growth during certain periods in July and the percentage of fruit buds formed. Chandler and Heinicke (5) have obtained an increase in vigour by defloration. When biennial bearing has been eliminated from consideration by making comparisons over a period of years, an increase in vigour has been found to be accompanied

by an increase in production, up to a certain point above which the production has either remained stationary or has decreased. Partridge (25) has reported a maximum crop with certain varieties of apples when the increase in trunk circumference averaged about two inches per year. Roberts (28) has found with the Wealthy that 20 to 25% of the terminals need to be over 10 inches long to maintain a condition conducive to annual bearing. Alderman and Auchter (1), Gardner (9), and Heinicke (14) have reported that maximum fruit bud production has accompanied moderate vigour with the apple.

Correlations between Leaf Area and Other Characteristics

The type of foliage has been found to have a direct bearing both on fruit bud formation and on vigour. Gourley (11) has found that the average leaf area is smaller during the on year than during the off year. Many investigators have reported that the average leaf area is greater on vegetative spurs than on bearing spurs (2, 12, 30). Magness, Overley and Luce (20, 21) have noted that the greater the leaf area per fruit, the higher the percentage of fruit buds formed. Claypool (6) has pointed out that any decrease in the size or efficiency of the leaves is accompanied by a lessened growth of the trunk. Overholser and Overley (23) have found a very close relationship between the total leaf area on trees of similar size and the average length of terminal growth.

EXPERIMENTAL PROCEDURE

As already noted in the first paper of this series, the orchard in which these investigations have been conducted contains 23 acres of apple trees, consisting of McIntosh, Jonathan, Delicious, Newtown, Wealthy and Duchess. Most of the trees have been affected to some extent with drought spot and related physiological disorders. During the period of experimentation, however, they have been making good vegetative growth. In the spring of 1931, a large portion of the 23 acres was divided into plots, of which about two-thirds were allotted to differential treatments, and one-third maintained as check plots. Except for the differential plot treatments, an attempt has been made to give uniform treatment in all respects to all the plots.

A large number of records have been taken each year on all the trees in the plots. Certain of these records have also been taken on the other trees in the orchard. Those records which will be used in this present report, and the methods by which they have been obtained, are as follows:

Trunk Circumference.—Obtained each year during the dormant season. At about one foot from the ground, two permanent marks have been maintained on opposite sides of the trunk, and the circumference has been measured at this position to the nearest millimetre. Prior to taking the measurement, the loose bark has been scraped off.

Terminal Length.—Obtained by the method recommended in the first paper of this series. From 1931 to 1935 inclusive, the length of each terminal was recorded separately, along with its diameter. In 1936, however, the lengths were added on a steel tape, and only the total length per tree recorded. This has lessened the time required per tree considerably.

Terminal Diameter.—All records used in this report have been taken at the base of the terminal, as noted in the first paper of this series. The recording of the terminal diameter in the plots was discontinued in 1936.

Percentage Bloom.—Obtained at the cluster-bud stage or soon after. The procedure used has been as follows: At one of the four points of the compass, a limb is selected which appears to be representative of that section of the tree with regard to amount of bloom. Starting at the tip of the limb and moving in towards the trunk, the operator counts a total of 25 new growths arising from terminal buds on (a) all terminals less than 3 cm. in length, (b) all laterals subtending two-year wood or older that are less than 3 cm. in length (three-year wood or older with some varieties), and (c) all laterals, no matter what their length, arising from blossom-spur thickenings of the previous year. These growths thus constitute a sample from the regular spur system of the tree. The number out of the 25 that are producing blossoms is recorded. Moving to the left, the operator repeats the process at each of the other three points of the compass, starting at points half-way in to the trunk, at the tip of the limb again, and well in towards the trunk respectively. Thus the different portions of the tree are well represented. The total number of growths counted that are bearing blossoms constitutes the "percentage bloom".

Percentage Set.—Obtained just before the start of the regular thinning period. The procedure used has been exactly the same as for percentage bloom. Thus the figure obtained for each tree represents the proportion of all the spurs (not of just the blossoming spurs) that still hold fruit at the time of recording. Owing to the set of fruit around the tree being so uneven in many cases, the figure obtained for percentage set is not always as reliable as that for percentage bloom.

The data obtained from these records have been used for correlation studies. Correlations have also been calculated between these records and the crop of saleable fruit; but since the apples have in many cases been severely affected with drought spot or corky core, the coefficients of correlation obtained are not reliable. The chief method used for studying the relationships between each two sets of data has been to chart the values in scatter diagram form. To assist in the interpretation of these diagrams the coefficients of correlation have been calculated for a large number of their distributions. In addition the various records on each of the plot trees have been charted year by year in "history chart" form: this method has been found especially useful in following out the changes occurring in each tree from year to year, and has constituted a very valuable supplement to the correlation methods.

RESULTS

Only those results are reported at this time that have been obtained from a study of the trees in the check plots. Accordingly, they have not been influenced by the differential treatments applied to the treated plots. The period covered by the studies has been from 1931 to 1936 inclusive, and the varieties used have been McIntosh, Jonathan and Delicious. For the sake of brevity, however, the data reported will be confined almost entirely to the findings of 1934 and 1935 —two years which have given fairly typical results—and to the McIntosh variety, which is represented by more trees

than either the Jonathan or Delicious. Except where otherwise stated, the coefficients of correlation reported have all been obtained from 58 normal-type McIntosh trees in the check plots.

The symbols of records used in the report are as follows:—

T — trunk circumference at start of year

I — increase in trunk circumference during year

L — average terminal length

D — average terminal diameter

B — percentage bloom

S — percentage set.

When two of these symbols are used together, the placing of a tick above one of them means that this one follows one year after the other: thus "$r_{T\check{I}}$" is read "correlation between T in any one year and I of the following year". A number after the symbol indicates the number of years used in obtaining the average: thus "L4" means "the average terminal length for four years". The statistical significance of each coefficient of correlation is indicated in the following manner:

(ns) — odds less than 19 : 1 (not significant)

(S) — odds between 19 : 1 and 99 : 1 (significant)

(HS) — odds greater than 99 : 1 (highly significant).

Correlations between Size of Tree and Vigour

In these studies, the size of tree is represented by the trunk circumference during the preceding dormant season, and the vigour by the increase in trunk circumference and the terminal length. "Vigour" is used in this paper in the sense of vegetative growth only. The correlations obtained in 1934 between trunk circumference and the above two dormant-season measurements of vigour were as follows:

$$r_{TI} = -0.301 \text{ (S)} \quad \text{(a)}$$

$$r_{TL} = -0.409 \text{ (HS)} \quad \text{(b)}$$

In both cases, there is a significant negative correlation; which means that as the size of tree has increased, the vigour has tended to decrease. A study of the scatter diagrams shows that the decrease in vigour has been taking place for the most part during two distinct periods in the life of the tree: first, when the young trees have come into bearing; and second, when the roots or branches have met those of the neighboring trees. These changes have been observed in the charts of both increase in trunk circumference and terminal length. Between the two periods of change other factors appear to have been more important than size of tree in influencing the vigour.

Correlations between Measurements of Vigour

The measurements of vigour that have been used for correlation work have been almost entirely dormant-season measurements. Of these, the increase in trunk circumference, the terminal length, and the terminal diameter have provided the most noteworthy results.

The increase in trunk circumference and the terminal length have been found to be correlated directly to one another. By way of example, that for 1934 was

$$r_{IL} = +0.437 \text{ (HS)} \quad . \quad . \quad .

It appears that biennial bearing has influenced the increase in trunk circumference of any one year in a similar manner to the terminal length of the alternate years.

It has also been found necessary to eliminate the differences in general vigour when the effects of biennial bearing on the increase in trunk circumference or the terminal length in successive years have been studied. The simple ratios such as those noted above were however unsatisfactory in this case: $\frac{I}{I'}$ and $\frac{I'}{I}$, being reciprocals, could not be correlated with one another. The most satisfactory method used has been to divide each measurement in any one year by the average for four years, to do the same for the following year, and to correlate the two sets of ratios. Thus the increases in trunk circumferences in 1934 and in 1935 were all divided by the average increases from 1933 to 1936, and the 1934 ratios correlated with the 1935 ratios:

$$r_{\frac{I}{I4}\cdot\frac{I'}{I4}} = -0.845 \text{ (HS)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(k)}$$

The same was done with the terminal length:

$$r_{\frac{L'}{L4}\cdot\frac{L'}{L4}} = -0.387 \text{ (HS)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(l)}$$

Here again, the positive correlations noted above (f, g) have become negative. It is apparent that trees that had been bearing biennially have tended to have a relatively large increase in trunk circumference one year and a relatively small increase the following year. The same has held true with the terminal lengths, though in this case the alternation has not been so marked. As would be expected from correlation (i) above, the larger increase in trunk circumference has occurred in the same year as the shorter terminal length.

The terminal diameter at the base has been found to be correlated directly with both the terminal length and the increase in trunk circumference. The correlation between the terminal length and its diameter in 1934 was

$$r_{LD} = +0.950 \text{ (HS)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(m)}$$

and between the terminal length and the square of the diameter,

$$r_{LD^2} = +0.914 \text{ (HS)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(n)}$$

The use of the cross-sectional area at the base of the terminal gives practically the same results as the use of the square of the diameter. Both of the above coefficients are higher than the average of those determined. The correlation between the terminal diameter and the increase in trunk circumference in 1934 was

$$r_{ID} = +0.498 \text{ (HS)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(o)}$$

These coefficients indicate (as did those reported in the first paper of this series) that the terminal diameter at the base has been closely related both to the terminal length and to those factors influencing the increase in trunk circumference, and that it has been more closely related to the former of these than to the latter. When a tree has been bearing biennially, the terminals have been narrower at the base in the on year than have those

of the same length in the off year. Their average length has however usually been sufficiently greater in the on year to give a greater diameter at the base that year in spite of the adverse effects of the heavier crop.

Correlations between Bloom and Set of Fruit

The correlation between the percentage bloom in any one year and that of the following year has been found to be negative. The 1934–35 results gave

$$r_{BB'} = -0.341 \text{ (HS)} \quad . \quad . \quad .

negative, and has lowered the significance considerably. The tendency has been for the increase in trunk circumference to be much less in the on year than in the off year, and on the other hand for the terminal length to be somewhat the longer in the on year. It might be noted that no consistently significant correlations have been found between the percentage bloom or percentage set and the terminal diameter; though ordinarily the diameter at the base is somewhat greater in the heavy crop year.

Leaf Area

No coefficients of correlation have been calculated between leaf area and the growth and fruiting of the tree. However, a large amount of observational evidence has indicated that the leaf area per unit of terminal length has been very closely correlated both with the terminal diameter and with the increase in trunk circumference. That is, the greater the leaf area, the greater the growth of the tree.

DISCUSSION

Mathematical calculations on the measurements of external characteristics of tree growth and fruiting cannot of themselves reveal fundamental laws concerning the physiological processes that occur in the tree. Because two measurements are found to be closely correlated, it does not follow that one is necessarily the cause of the other. A significant correlation is however an expression of a true mathematical association; and it is obvious that underlying this relationship there must be a physiological association of some kind. Thus the findings of a strictly mathematical study may be of value in pointing out the need for further physiological studies, or in corroborating the findings of physiological studies that have already been made.

The results that have been reported in this paper are chiefly corroborative in nature. In the first place, the correlations obtained are similar to those already reported by a number of other investigators (7, 19, 22, 24, 25, 28). And in the second place, some of the chemical and morphological changes that have been shown by other workers to occur within the tree, appear from this investigation to be reflected in external characteristics. Thus it has been shown by Hooker (17), Roberts (28), Finch (8), and many others that there is a greater production of xylem tissue and a greater storage of carbohydrates during the off year than during the on year. This condition is accompanied by the production of a thicker annual ring of new wood and bark during the off year. It is also accompanied by a larger production of fruit buds, as would be expected from the investigations of Kraus and Kraybill (18), Hooker (17), Harvey (13), Roberts (28) and others; so that an off year should normally be followed by an on year. As already noted in the review of literature, it has been shown (13, 26, 28) that the linear growth of the terminal is made largely at the expense of stored-up foods, and may therefore be affected by the growth and fruiting conditions of the year before.

Both physiological and mathematical studies have thus shown that the different parts of a tree are closely associated with one another. Accordingly, it is possible not only to outline those relationships that actually exist, but also to suggest what is cause and what is effect. The results reported above consist chiefly of a number of mathematical relationships,

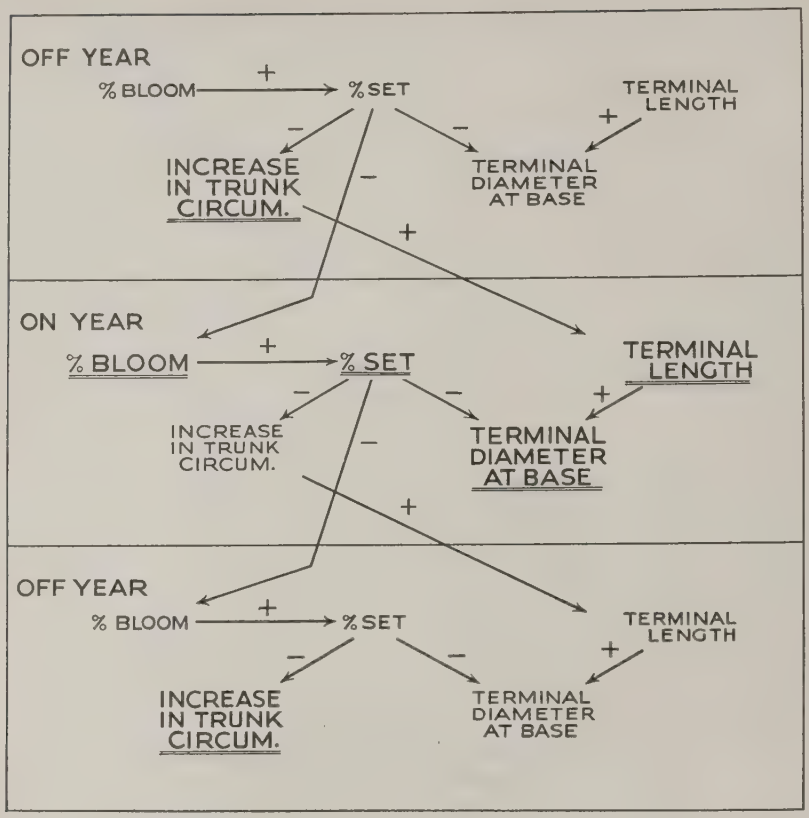

FIGURE 1. Effects of biennial bearing on measurements of growth and fruiting. The arrows suggest the direction of cause and effect. A + sign beside an arrow indicates a positive correlation, and a − sign a negative correlation. Large type (underlined) indicates that the measurement is relatively large, and small type that it is small. Since the percentage set and the quantity of fruit picked would occupy the same place in the diagram, in so far as their effects on other measurements are concerned, the latter has been omitted. This chart is based on six years of statistical study in an experimental orchard at Kelowna, B.C.

expressed as coefficients of correlation. Some of these are positive, some negative; some high, some low. Where the coefficient is high, it is obvious that the relationship is a much closer one than where it is low. In connection with the effects of biennial bearing, for example, there appears to have been a very close association between the amount of fruit set and the increase in trunk circumference. This and the other more obvious relationships suggested by the correlations are depicted in "history chart" form in Figure 1. An attempt has been made in this chart to link together those measurements that have been most significantly correlated, and at the same time to suggest which is the more closely associated with cause and which with effect. Thus an arrow points from percentage set to increase in trunk circumference, indicating that in so far as this relationship is

concerned, the amount of crop and the set of internal conditions that accompany it are instrumental in affecting the size of the annual layers of wood and bark. However, no attempt has been made in the chart to denote the position or type of the internal conditions that have accompanied each of the correlations. Nor has any attempt been made to denote those correlations that appear to be only secondary in importance. It will be noted, too, that "crop picked" has been omitted. This is due to the fact that in so far as the effects on the tree are concerned, it would appear to occupy the same position as percentage set.

Although in this chart the percentage bloom is related back directly to the percentage set and its accompanying conditions of the year before,

1931	B – 8		S – 6		L – 15.4
		I – 3.1		D – .59	
1932	B – 91		S – 29		L – 30.4
		I – 2.4		D – .64	
1933	B – 37		S – 12		L – 19.7
		I – 2.4		D – .56	
1934	B – 94		S – 24		L – 27.7
		I – 1.9		D – .57	
1935	B – 12		S – 11		L – 20.5
		I – 4.7		D – .54	
1936	B – 97		S – 28		L – 30.9
		I – 1.7		D – *	

* Not obtained.

FIGURE 2. "History chart" for six years of tree EE2, a McIntosh tree bearing heavily in the even years. In the on years, the % bloom, the % set, the terminal length, and the terminal diameter at the base have all been larger than in the off years, while the reverse has held true for the increase in trunk circumference. The size of the crop has varied with the % set.

B—% bloom; S—% set; L—terminal length, in cm.; D—terminal diameter, in cm. I—increase in trunk circumference, in cm.

1931	B – 68		S – 30		L – 12.9
		I – 1.2		D – .56	
1932	B – 2		S – 2		L – 7.4
		I – 4.2		D – .54	
1933	B – 90		S – 38		L – 21.0
		I – 1.9		S – .59	
1934	B – 4		S – 2		L – 8.3
		I – 3.6		D – .54	
1935	B – 82		S – 67		L – 29.9
		I – 1.5		D – .60	
1936	B – 12		S – 2		L – 20.1
		I – 3.1		D – *	

* Not obtained.

FIGURE 3. "History chart" for six years of tree Q28, a Delicious tree bearing heavily in the odd years. The size of the crop has varied with the % set. For the terminology, see Figure 2.

it should be borne in mind that the amount of bloom has been found (31, 32) to be affected as well by the time during the previous year at which the terminals ceased growth. There is no doubt a very close association between these two factors. In any case, it would seem from blossom thinning tests (2, 3, 15, 27), in which total defloration one year has brought about a heavy bloom again the following year, that the production of fruit buds is more directly related to the percentage set than to the terminal growth.

In order to give practical expression to the relationships outlined in Figure 1, two examples of data obtained in the field are presented in Figures 2 and 3, in history chart form. In Figure 2 are the data from a tree bearing in the even years; and in Figure 3, from a tree bearing in the odd years. These two trees are rather extreme types of biennial bearers. Moreover, they have persisted in the alternation of bearing more regularly than have most of the trees. With most trees, the usual order of bearing has for various reasons been upset quite frequently. One of the chief causes of this has been the loss of a very high percentage of the bloom due to weather conditions or to the tarnished plant bug. An example of this is given in Figure 4.

1931	B – 24	I – 3.8	S – 13	D – .68	L – 26.8
1932	B – 89	I – 2.9	S – 9	D – .73	L – 37.6
1933	B – 90	I – 2.1	S – 28	D – .62	L – 31.8
1934	B – 54	I – 2.7	S – 14	D – .69	L – 27.2
1935	B – 78	I – 2.4	S – 33	D – .73	L – 38.4
1936	B – 45	I – 3.8	S – 2	D – *	L – 33.0

* Not obtained.

FIGURE 4. "History chart" for six years of tree BB2, a McIntosh. The tarnished plant bug attacked the blossom buds in the spring of 1932, with the result that the on year was changed from the even year to the odd year, with accompanying effects on the measurements of vigour. The loss of bloom was especially heavy again in 1936. The fruit has been badly affected with drought spot. For the terminology, see Figure 2.

SUMMARY

Studies were made of the relationships between measurements of growth and fruiting of the apple tree. The methods of study included the use of the scatter diagram, of the coefficient of correlation, and of individual tree charting. The investigations covered a six-year period, from 1931 to 1936. The principal findings were as follows:

1. As the size of the tree increased, the rate of increase in trunk circumference and terminal length tended to decrease.

2. Vigorous trees were found to grow more strongly in all respects than weak trees. Positive correlations were obtained between terminal length and increase in trunk circumference, both in the same year and in

alternate years; also between each of these in any one year and the same in alternate years. When however the differences in vigour were eliminated, biennial bearing was found to produce a longer terminal growth and a smaller increase in trunk circumference together during one year, and the reverse the following year.

3. The terminal diameter was correlated directly with both the terminal length and the increase in trunk circumference.

4. Negative correlations were found between the percentage bloom or set one year and the same the following year.

5. Negative correlations were obtained between the percentage bloom or set and the increase in trunk circumference, but positive correlations between the percentage bloom or set and the terminal length.

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Résumé

Étude de la végétation et de la fructification des pommiers dans le verger. II. Corrélations entre la pousse et la fructification. J. C. Wilcox, Station expérimentale fédérale, Summerland, C.-B.

Cette étude porte sur les rapports existant entre les mesures de la pousse et de la fructification du pommier. Elle comportait l'emploi du schéma pointillé, du coefficient de corrélation et du relevé de chaque arbre séparément. Les recherches couvrent une pédiode de six ans, de 1931 à 1936. Les constatations principales sont les suivantes: A mesure que la grosseur de l'arbre augmente, la rapidité d'accroissement de la circonférence du tronc et de la longueur terminale tend à décroître. On a constaté que les arbres vigoureux poussent plus vigoureusement sous tous les rapports que les arbres faibles. On a obtenu des corrélations positives entre la longueur terminale et l'augmentation de la circonférence du tronc, aussi bien dans la même année qu'en des années alternatives. Cependant, quand les différences de vigueur sont supprimées, on constate que la fructification bisannuelle produit une pousse terminale plus longue et une moindre augmentation dans la circonférence du tronc pendant une année, et l'inverse l'année suivante. Le diamètre terminal se reliait directement à la longueur terminale et à l'augmentation dans la circonférence du tronc. On a constaté des corrélations négatives entre le pourcentage de fleurs ou de nouaison une année et l'année suivante. On a obtenu des corrélations négatives entre le pourcentage de fleurs ou de nouaison et l'augmentation de la circonférence du tronc, mais, par contre, des corrélations positives entre le pourcentage de fleurs et de nouaison et la longueur terminale.

A FIELD EXPERIMENT ON THE CONTROL OF THE EUROPEAN CORN BORER, *PYRAUSTA NUBILALIS* HUBN., BY *BEAUVERIA BASSIANA* VUILL[1]

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In 1935, M. Timonin and I. L. Conners, of the Division of Botany, Experimental Farms Branch, showed in field experiments at Ottawa that it was possible to infect and cause the death of larvae of the European corn borer with *Beauveria Bassiana* Vuill. by the application of spores of this fungus to the infested corn. The borer infestation has been established artificially by the application of egg masses to the plants as the local natural infestation would have been both too sparse and too uncertain to assure suitable conditions for a satisfactory experiment. In 1936, as a result of these studies a comparable field test with natural infestation in the heart of the corn borer infested territory was suggested. Accordingly, the study was continued with the co-operation of the staff of the Chatham (Ontario) laboratory of the Entomological Branch.

Two problems of chief concern were to determine first, whether the spores of *Beauveria Bassiana* Vuill., disseminated in the field would reduce the population of corn borers in the Chatham region and, second, when the spores should be disseminated. A third possible problem of effect of increase in the quantity of spores used per acre was not investigated since the work of Bartlett and Lefebvre (1) together with unpublished work by I. L. Conners had shown that high levels of application increase, if but slightly, the mortality.

REVIEW OF LITERATURE

Metalinkov and Toumanoff (4) found that *Beauveria Bassiana* Vuill., among other fungi, readily infected larvae of *Pyrausta nubilalis* Hubn., and that this infection could be effected by spraying the larvae or their host plants with spore suspensions. Lefebvre (3) reported an epidemic of *Beauveria Bassiana* Vuill. on larvae of the European corn borer within a laboratory. This appears to be the first reported occurrence of *Beauveria Bassiana* Vuill. on corn borer in North America. The disease was found to be easily spread within the laboratory and amenable to dissemination in the field. Lefebvre (3) dealt with, among other questions, the relative virulence of *Beauveria Bassiana* Vuill. and of *Beauveria globulifera* Speg. as pathogens on the corn borer. The former species, introduced to America, proved far more effective than the indigenous species. Bartlett and Lefebvre (1) reported extensive field tests on *Beauveria Bassiana* Vuill. against European corn borer and found the larvae in the field readily susceptible to attack by this form when the spores were diluted with flour.

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Steyaert (5) discussed the control effected by *Beauveria Bassiana* Vuill. on *Stephanoperes hampei* Ferr. as connected with the culture of coffee in the Belgian Congo and decided that the introduction of the disease into regions where it does not exist may be useful for the control of this pest. He pointed out that the time of application of spores is important and that the infection must be effected before the insect had tunnelled into the berry.

MATERIALS AND METHOD

The isolate of *Beauveria Bassiana* Vuill. used in these experiments was obtained from mummified corn borer larvae, which had been received from the Dominion Parasite Laboratory, Belleville, Ontario. Spores were obtained in quantity for the field experiment by growing the fungus on soy-bean mash in petri dishes. The mash was prepared as follows: washed soy-beans were barely covered with tap water and allowed to soak for 18 to 24 hours, then they were passed through a meat chopper and tap water was added sparingly to give the mash the consistency of porridge. Petri dishes, containing a thin layer of soy-bean mash, were sterilized in the autoclave for 30 minutes under 15 pounds pressure. After the dishes were cool, the medium was inoculated with spores of the *Beauveria* and incubated at 25° C. After four to five days of incubation the fungus developed a white, uniform growth of mycelium over the dish which rapidly assumed a creamy, chalky appearance with the copious production of spores. After the culture had partly dried up, the spores were brushed off the medium with a small brush and collected in a flask. The inoculum was prepared by thoroughly mixing together weighed quantities of spores and flour at the rate of 40 grams of spores to 16 pounds of flour. This inoculum was prepared in two lots, one for the first application and another for the second. The amount required for each block or plot was packaged separately at Ottawa before shipment. Slightly over 100 grams of spores were required for the experiment. As the yield per plate varied from 0.1 gm. to 0.4 gm., between 300 to 400 petri dishes were required.

Spores were applied on two dates, July 8 and July 19, at two levels, 0 grams and 40 grams, per acre, as indicated in Table 1. The two dates of dusting fell, respectively, early in the period of oviposition and at the height of the period. In the interval the corn had come generally into tassel. The inoculum was dusted with great care from a cheesecloth bag into the throat of the corn plants and at the second application new growth received especial attention. It may be noted that the untreated plots did not receive an application of flour from which the spores were omitted.

Table 1.—Combinations of variations of treatments

Treatment number	Application on July 8	Application on July 19
1 (untreated)	0 gr.	0 gr.
2	0 gr.	40 gr.
3	40 gr.	0 gr.
4	40 gr.	40 gr.

The plots were square and contained 144 hills of the cross-checked corn used in the experiment. The two outer rows of hills on all four sides of each plot served as a buffer. Four plots, to each of which was

assigned one of the treatments of Table 1, formed a square block. The treatments were randomized, independently in each block, as is common in agronomic research, by use of random sampling numbers, Tippet (6). The blocks, replicated fifteen times (see Table 2), formed a contiguous and compact mass in one field. The four labourers who made the counts were allotted whole blocks so that variability between them would not affect the standing of the treatments. Also, each operation such as dusting or sampling was carried out on all plots of a block as nearly simultaneously as possible.

Records were secured from limited sampling, because it was required to take successive counts at each of which the material examined was necessarily destroyed. In sampling, from each plot eight hills distributed equally between four sub-plots were examined. The two hills from each sub-plot were chosen strictly at random for each count. The choice was again made with random sampling numbers. A first examination was carried out, before the great autumnal migration and reduction in population, during the period August 18–21, inclusive, a second during October 19–22, inclusive, and a third is to be made in the spring of 1937.* Before examination was undertaken the non-technical observers were instructed carefully in the differences between the various borers of corn and then given a cutting exercise for a morning.

PRESENTATION OF DATA

In Table 2, the number per plot of corn borers, by treatments and by blocks, is presented for the counts made in August and in October. The values show the total number of borers surviving in the eight hills examined in each plot at each time.

TABLE 2.—NUMBERS OF CORN BORERS PER PLOT

Block	Treatment No. 1		Treatment No. 2		Treatment No. 3		Treatment No. 4	
	No application		Early application		Late application		Double application	
	First count of Aug. 18	Second count of Oct. 19	First count of Aug. 18	Second count of Oct. 19	First count of Aug. 18	Second count of Oct. 19	First count of Aug. 18	Second count of Oct. 19
1	38	13	24	7	28	11	22	3
2	39	33	47	39	29	4	19	19
3	41	39	68	25	36	16	23	13
4	27	42	71	11	45	18	34	4
5	50	14	31	25	26	11	45	8
6	65	49	73	57	57	16	63	13
7	59	39	88	30	49	13	55	19
8	52	21	45	12	35	5	43	6
9	77	26	47	18	35	1	82	12
10	84	44	59	31	58	22	45	9
11	61	40	64	28	50	12	50	15
12	38	19	51	19	13	9	32	11
13	62	47	107	24	46	8	59	7
14	136	26	79	27	39	20	72	24
15	88	32	90	27	68	12	74	18
Total	917	484	944	380	614	178	718	181

* All possibility of making the third count was removed by the accidental destruction of the overwintered corn stalks by fire, May, 1937.

DISCUSSION OF RESULTS

The control ascribable to any treatment is determined below by finding the relative magnitude, expressed in percentage form of the number of borers by which plots subjected to the given treatment fell short of the number on plots subjected to no treatment or treatment No. 1. The reduction effected by the various treatments at the time of the August and October examinations is presented in Table 3.

TABLE 3.—REDUCTION IN POPULATION EFFECTED BY VARIOUS TREATMENTS

	Treatment No. 2	Treatment No. 3	Treatment No. 4
	Early application	Late application	Double application
First count of August 18	−3%	33%	22%
Second count of October 19	21%	63%	63%

From Table 3, it can be seen that an appreciable reduction in infestation had been effected by August and a very marked reduction by October. The early application was markedly less effective than the late. The negative reduction found at the time of the count in August is ascribable to a chance excess of borers in the treated plots over borers in the untreated plots. Such a situation must tend to arise when no appreciable control is effected by a treatment. Double application apparently gave no effect over and above late application.

The arrangement of plots was such as to avoid giving bias to the effect of treatments. Sources of mortality, such as feeding of birds, other than the experimental pathogen were more or less common to all plots and should be equalized from treatment to treatment by the randomization of plots. The fifteen replications ensured that regional effects which might have made some one treatment appear unduly effective tended to cancel out. The compact blocks, of course, ensured that regional heterogeneity would be minimal in effect so that the variability of percentage controls in Table 3 is as low as possible.

In the second examination, in October, the effects may have been obscured to some extent by migration, for a few individuals attacked by *Beauveria Bassiana* Vuill. were found in most of the control plots. Nevertheless, the difference in population between the treated and untreated plots is very much less marked in the early examination than in the late. Moreover at the latter time many larvae were noted dying or freshly dead from the disease so that further reduction was anticipated.

SUMMARY

The present work indicates that by dissemination of the spores of *Beauveria Bassiana* Vuill. to infested corn plants a marked reduction in the population of corn borers may be effected. There is an indication that the time of application is of the greatest importance and worthy of further investigation. The fact that some disease was found in the control plots in the second examination suggests that the buffers about the plots

were inadequate. Such inadequacy must have resulted in a lowering, however slight, of the apparent percentage control effected by treatment, the late date of occurrence of heavy kill removes the benefit of treatment from the year of application to the subsequent year.

ACKNOWLEDGMENTS

This work is a co-operative project between the Division of Botany, Experimental Farms Branch, and the Entomological Branch (Chatham Laboratory), both of the Dominion Department of Agriculture. I. L. Conners, Plant Pathologist, in the Division of Botany, made many valuable criticisms of the draft outline of the project. The Division of Botany produced and shipped the inoculum of spores of *Beauveria* and carrier to Chatham, Ontario. D. A. Arnott, Entomological Laboratory, Chatham, assisted by criticism, suggestion and field work in carrying out this project.

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BOOK REVIEW

CANADIAN ANIMAL HUSBANDRY. J. W. G. MacEwan and A. H. Ewen. Published by Thomas Nelson & Sons, Toronto. Price $3.75.

It has been some years since a book on animal husbandry written by a Canadian author has appeared. Professor MacEwan and Associate Professor Ewen of the University of Saskatchewan have collaborated to produce an exceedingly useful publication. They do not attempt to exhaust any one phase of animal husbandry, but rather "to include under one cover the essential points about the theory and practice of breeding, feeding, management and related problems. It has been the constant aim of the authors to treat the subject matter in such a manner that the book would serve as a text for students of agriculture and a guide and reference to practical live stock breeders." This is a difficult task, but it must be acknowledged that the authors have succeeded admirably in accomplishing their purpose. The book is divided into the following sections:

1. The Principles of Breeding.
2. Breeds of Live Stock in Canada.
3. Principles of Nutrition.
4. Feeds.
5. Feeding and Management of Farm Stock.
6. Marketing of Live Stock.
7. Farm Meats.

For students in agricultural schools this text should be highly satisfactory as it covers the field in condensed form. The illustrations are the best we have seen in a Canadian agricultural text book. The section on farm meats is a particularly valuable addition.

H. L. T.